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PHYSIOLOGICAL ASPECTS OF FLYING

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PHYSIOLOGICAL ASPECTS OF FLYING

FOREWORD

During the last war and until a few years ago it was said that a pilot is only as good as his airplane. This is no longer true. In the race for higher speed and greater altitude, the performance of airplanes has moved relentlessly ahead until now it is the airplane that is vastly superior to the pilot. In fact, it would seem that, like Frankenstein, we have created a monster which, if not handled correctly, can easily destroy us by its actions.

The inventors, engineers, and manufacturers of the new airplanes are doing the jobs demanded of them: building airplanes capable of greater range, greater altitude, and greater speed, and making them large enough to carry enormous loads. Now it is the job of the flight surgeons, the scientists, and the doctors to close the gap between the potentialities of the airplane and the limitations of the flyer. That they are doing so cannot be disputed.

*This manual supersedes TM 1–705, 25 July 1941.

The flight surgeons cannot find the answer to a problem until they know what the problem is. After a new type of airplane is developed, specific problems arise. These problems are met and they are solved. Each day we come closer to the long-dreamed-of complete mastery of our newest environment—the air.

The purpose of this manual is to endeavor to explain in everyday terms the various physical and physiological problems that arise during flying, and to give in detail the latest knowledge of proved solutions to these problems.

In the comparatively short history of aviation it has been shown that the majority of crashes are not caused by mechanical faults but by the pilot's error. There are reasons for these failures. In this manual some of these reasons will be enumerated and an endeavor made to explain how they can be avoided. It is important that the airman realize his shortcomings and weaknesses and learn how to compensate for or prevent them.

When a crew takes to the air on a mission it leaves behind the flight surgeon. If one of the flyers fails through his own lack of knowledge and training, he does more than jeopardize his own life and the lives of the other crew members—he jeopardizes the safety of his country. A mission may fail simply because an airplane is flown at 28,000 feet instead of 35,000 feet, as a result of one of the men developing "bends."

The ancient Greeks, who strived for the ideal in physical and mental perfection, had a great motto: "Know thyself." The flyer, by following those two simple words, will never fail either himself or his country.

Section I

ATMOSPHERE OF THE EARTH

1. Composition of the earth's atmosphere.—*a.* The earth is enveloped by a mixture of gases and water vapor which extends for more than 100 miles above the earth's surface. This mixture is known as the earth's atmosphere.

b. The upper atmosphere is divided into three concentric spheres: the *troposphere*, which immediately surrounds the earth; the *strato-*

sphere, which in turn surrounds the troposphere; and that section between them, the *tropopause*. (See fig. 1.)

(1) The troposphere is characterized by a constant rate of decrease in air temperature and water vapor content as the altitude above the earth increases. Weather phenomena occur in this region.

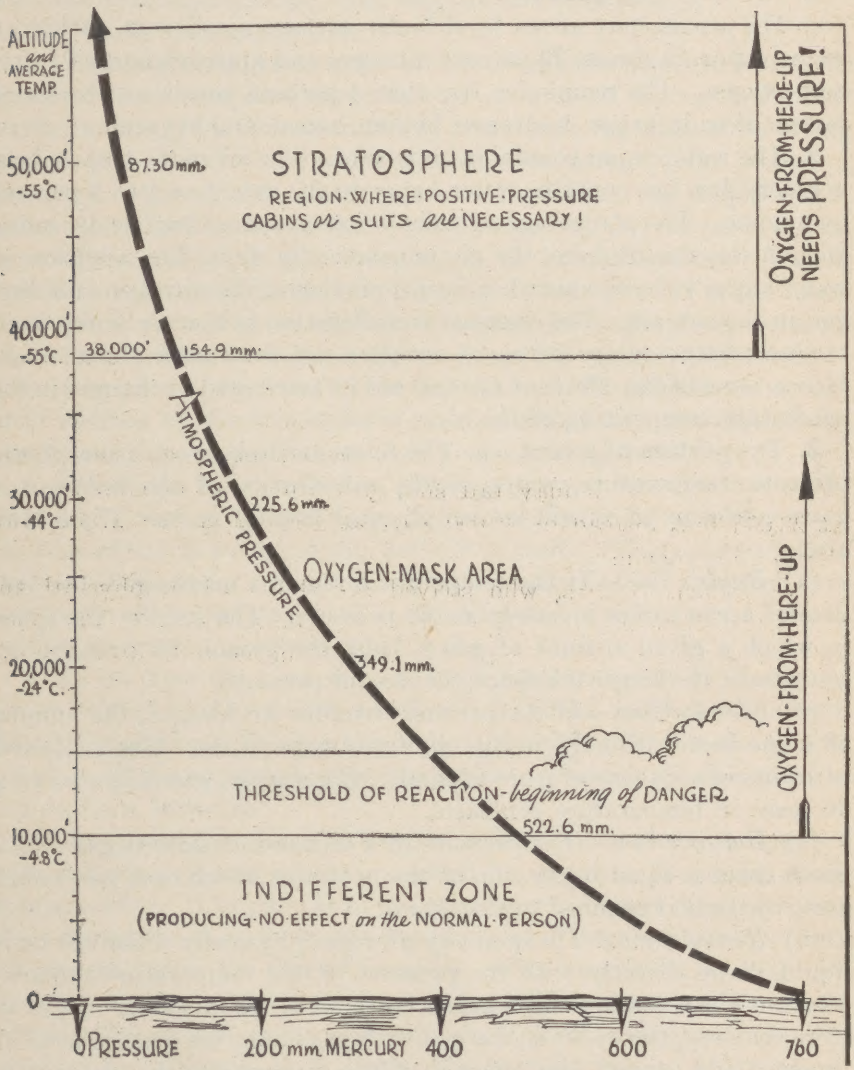

FIGURE 1.—Chart of the earth's atmosphere.

(2) The tropopause has no constant height. It varies with latitude. It is closest to the earth at the poles (approximately 6 miles) and farthest away at the equator (approximately 10 miles).

(3) The stratosphere is characterized by a uniform temperature which varies little with altitude. However, it does vary with latitude. The warmest stratosphere temperatures occur over the poles, where temperatures as warm as −40° C. may exist. The coldest stratosphere temperatures occur over the equator, where temperatures as low as −80° C. have been observed.

c. The atmosphere at sea level under average conditions, excluding water vapor, is almost 79 percent nitrogen and approximately 21 percent oxygen. The remainder, less than 1 percent, consists of traces of carbon dioxide, argon, hydrogen, helium, xenon, and krypton.

d. The water vapor content is important. The air in the troposphere is rarely dry, but contains water vapor to the extent of 1 to 5 percent by volume. The percentage of moisture decreases at higher altitudes, and, in the stratosphere, the air is practically dry. The addition of water vapor reduces somewhat the proportion of the nitrogen and oxygen in the wet air. The essential consideration is that *on a dry basis the percentage composititon of air does not vary with the altitude.* Hence, none of the effects of altitude can be attributed to changes in the percentage composition of the air.

2. Properties of gases.—*a.* The relationship between atmospheric pressure, temperature, water vapor, and density of the mixture of gases conforms to certain known physical laws of gases. These laws are:

(1) *Boyle's law.*—If the temperature remains unchanged, the volume of a gas varies inversely as the pressure. The smaller the space in which a given amount of gas is held, the greater its pressure or, conversely, the larger the space, the less the pressure.

(2) *Charles' law.*—If the pressure remains unchanged, the volume of a gas varies directly as the absolute temperature. Gas subjected to an increase in temperature expands. Conversely, gas subjected to a decrease in temperature contracts.

(3) *Dalton's law.*—The pressure of a mixture of several gases in a given space is equal to the sum of the pressures which each gas would exert by itself if confined to that space.

(4) *Henry's law.*—The quantity of a gas physically dissolved by a liquid varies directly with the pressure, if the temperature remains constant. An example of this is a bottle of charged water. If, as is quite common, the water is charged with gas under ten atmospheres of pressure and capped, the removal of the cap exposes the water to a pressure of only one atmosphere, and nine-tenths of the gas escapes in the form of bubbles.

b. The physical properties of gases must be understood in order to arrive at a proper knowledge of the gaseous mixture called the atmosphere:

(1) Gases under most conditions act like fluids.

(2) Fluids do not offer permanent resistance to forces tending to produce a change in shape when they are free to move.

(3) Gases are compressible.

3. Atmospheric pressure.—*a.* The weight or pressure which the gases of the atmosphere exert on a given area of the surface of the earth can easily be demonstrated by the classic example of inverting a glass tube closed at one end and filled with mercury, into a bowl of mercury. At sea level, under standard conditions, the weight of the gases exerts sufficient pressure (14.7 lbs. per sq. in.) to push up the mercury in the glass tube to a height of 760 millimeters. This is called the standard barometric pressure at sea level. Further demonstrations show that as altitude increases, the atmospheric pressure decreases, for there is less air above—hence less weight, and therefore less atmospheric pressure. (The pressure of 14.7 pounds per square inch exerted by the atmospheric gases is called one atmosphere and represents the average atmospheric pressure at sea level.)

b. Due to the various factors affecting gases, a base line was established in order to compare one gas to another. Because the water content of air is not constant, dry air is used. The temperature is taken at 0° C. under a constant sea level pressure of 760 millimeters of mercury. Any gas sample is reduced to these conditions of "standard" temperature, pressure, and dryness.

c. To the flyer the most important physical property of the atmosphere is the actual pressure of the air in which he flies. His well-being, his ability to think and to reason, are dependent on the partial pressure of the oxygen he breathes which, in turn, depends upon the atmospheric pressure.

d. The partial pressure of oxygen is that portion of the standard atmospheric pressure which is exerted by oxygen. It can be determined easily. If 21 percent of the atmosphere consists of oxygen, and the atmosphere at sea level has a pressure of 760-mm of mercury, then 21 percent $\times$ 760 = 160-mm of mercury. (See par. 2*a*(3).) With the decrease in barometric pressure occurring with increasing altitude, the partial pressure of oxygen in the atmosphere correspondingly decreases; for example, to determine the partial pressure of oxygen at 18,000 feet where the atmospheric pressure is approximately 380-mm of mercury, multiply 21 percent by 380, thus obtaining 80-mm of mercury.

e. Oxygen is a primary requisite for the normal functioning and well-being of all animals. The passage of the required amount of oxygen into the tissues is dependent upon a whole series of events. The partial pressure of oxygen in the atmosphere determines the pressure of oxygen in the lungs. This in turn determines the pressure of oxygen in the blood. The latter determines how much oxygen is available to the tissues.

f. As stated in paragraph 1*d* the *percentage* of oxygen in the air remains the same regardless of the altitude. However, with increasing altitude the atmospheric pressure decreases and hence the *partial pressure* of oxygen decreases. In order to keep the tissues of the body supplied with oxygen, the pressure of oxygen in the lungs, as one ascends, must be maintained at a level equivalent to sea level conditions. It is readily apparent that this can be done by increasing the percentage of oxygen in the inspired air. For example, as shown in *d* above, at sea level the partial pressure of oxygen in the air is 160-mm of mercury, whereas at 18,000 feet it is only 80-mm of mercury. If, then, enough oxygen were added to the air at 18,000 feet to make it contain 42 percent of oxygen, the partial pressure would be $42 \times 380 = 160$-mm of mercury, or the same as that at sea level. Hence, it stands to reason that as one ascends, more and more oxygen must be added to the inspired air to maintain the required oxygen pressure in the lungs. Above 30,000 feet, 100 percent oxygen must be breathed.

4. The United States Standard Atmosphere.—*a.* An altimeter gives an interpretation of a given barometric pressure in meters or feet. The pressure of the immediately surrounding air is a relatively simple measurement, but its calibration in meters or feet is mainly theoretical, since it is based on the assumption that the column of air is of uniform temperature. This is invalid and leads to incorrect measurements of altitude, unless corrections are made for the outside air temperature.

b. It is emphasized in instructions to all flying personnel, especially to those who participate in high-altitude flights, that all criteria for the use of oxygen equipment are based on the actual reading of the altimeter in the airplane and not on the true height above sea level. An error of 500 feet or more at altitudes over 39,000 feet can make a great difference in a flyer's performance.

c. The Weather Bureau, in conjunction with the Bureau of Standards, in 1924 devised the present United States Standard Atmosphere. For the sake of setting up a norm it was arbitrarily assumed that—

(1) At a latitude of 40° in the United States, the temperature decreases linearly with altitude until the height of about 35,000 feet, above which the temperature is assumed to be constant.

(2) The temperature of the stratosphere is approximately −55° C.

(3) The air is dry.

(4) The air is a perfect gas, obeying the gas laws. (The calculation of the density of air from its pressure and temperature is an application of Boyle's and Charles' laws.)

(5) Gravity is constant at all altitudes.

d. Some physical properties of the United Sates Standard Atmosphere are given in Table I. Although this calibration is used by all Army Air Forces aircraft, it is not used internationally.

e. Atmospheric pressure decreases to half value at 18,000 feet, whereas the density decreases to half value at 21,500 feet.

TABLE I

Altitude feet	Pressure			Temperature	
	Height		Pounds per square inch	°C.	°F.
	Inches	Millimeters			
Sea level	29. 9	760	14. 7	15	59
1,000	28. 9	733. 2	14. 2	13	55
5,000	24. 9	632. 2	12. 2	5	41
10,000	20. 6	522. 7	10. 1	−5	23
15,000	16. 9	428. 7	8. 3	−14	5. 5
18,000	14. 9	379. 4	7. 4	−20. 7	−5. 4
20,000	13. 8	349. 2	6. 7	−25	−12
25,000	11. 1	281. 9	5. 45	−34	−30
30,000	8. 9	225. 5	4. 4	−44	−48
33,000	7. 7	195. 1	3. 9	−50. 7	−59. 2
35,000	7	178. 8	3. 5	−54	−66
40,000	5. 5	140. 7	2. 7	−55	−67
45,000	4. 4	110. 7	2. 1	−55	−67
50,000	3. 4	87. 4	1. 7	−55	−67
55,000	2. 7	68. 8	1. 3	−55	−67
60,000	2. 1	54. 1	1. 1	−55	−67
65,000	1. 7	42. 7	. 82	−55	−67

The pressure is a fourth at 33,500 feet, while the density ratio is only a third at 33,000 feet.

f. Aerodynamically, the speed of the airplane, the pull of the propeller, the lift of the wing, and the trajectory of the bomb are judged not in terms of pressure altitude (the actual reading on the altimeter) but by performance in air of equivalent density and viscosity. For this purpose the term "density altitude" is used as the independent variable on which all aerodynamic properties during flight are based.

g. During flight every pilot is equipped with an "Aero Dead Reckoning Slide Rule—Dalton Model B" which can be used to calculate the density altitude from the observed altimeter reading and observed outside temperature. The rule will show that—

(1) The pressure altitude (reading on the altimeter) equals the density altitude when the outside temperature equals the corresponding temperature for the Standard Atmosphere.

(2) For every degree centigrade the temperature of the outside air is above the standard temperature, the density altitude is approximately 100 feet above the pressure altitude (altimeter reading); also, for each degree below the standard, the pressure altitude is 100 feet below density altitude.

h. It should always be remembered that—

(1) Aerodynamically, airplane performance is judged in terms of true altitude. When flying at low altitudes it is important that the pilot make the necessary correction for the obvious reason that his airplane might crash into a mountain.

(2) Physiologically, human performance is judged by the actual reading on the altimeter because it is the pressure of the atmosphere that affects the human system. Thus, on a hot day, a pilot might read his altimeter at 40,000 feet. The outside temperature scale is −32° C. The pilot then calculates that he is at a true or density altitude of 43,000 feet. On another day, this time in winter, he is again at 40,000 feet on the altimeter. The outside temperature, however, reads −75° C. He makes the correction and learns he is at a density altitude of only 38,000 feet. He continues to go up in an effort to duplicate his previous effort. At 43,000 feet on the altimeter, if he can focus his eyes and read it, and with the outside temperature still at −75° C., the pilot makes his correction—if he is able to think that well, which is doubtful—and learns that he is at 41,000 feet. He returns to the ground, a puzzled man, until it is explained to him that, as far as he is concerned, physically, the altimeter is the reading that affects his well-being and not the density altitude.

5. Atmospheric moisture.—*a.* Virtually all the moisture in the atmosphere is confined to the troposphere. This is evidenced by the relatively rare occurrence of cloud forms in the stratosphere.

b. Vapor trails are cloudlike formations usually occurring at the ends of the wings. They appear when the airplane is between 25,000 and 35,000 feet from the ground and the outside temperature is near −18° C. A permanent cloud is left behind the airplane, thus producing tactically a very dangerous situation if the airplane is on a mission over enemy territory. Vapor trails can be avoided by the pilot going to either lower or higher altitude levels. (At low altitudes, with the weather close to freezing, a small thin, stationary cloud will sometimes be observed along the leading edge of the wing. This type of condensation reevaporates rapidly and leaves no trail.

Section II

EFFECTS OF HIGH-ALTITUDE FLYING UPON RESPIRATION AND CIRCULATION

6. Respiration.—*a.* To understand the cause of oxygen lack, it is necessary to know the fundamentals of respiration. Respiration, or breathing, is the function by which air is drawn into and pushed out

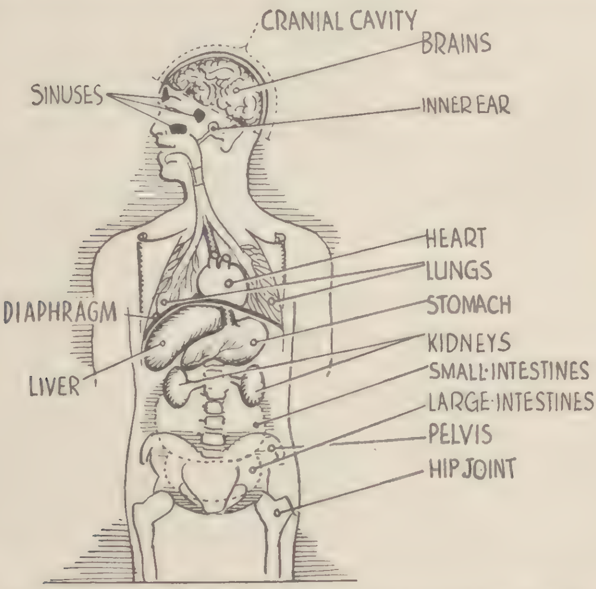

FIGURE 2.—Principal organs of upper part of the human body.

of the lungs. It consists principally of the exchange of oxygen and carbon dioxide. Oxygen is taken into the body and utilized to burn food. From this process, energy is derived to operate all the mechanisms necessary to keep the body alive and active. The waste gas of this combustion, carbon dioxide, is then eliminated. (See fig. 2.)

b. The respiratory exchange of gases takes place in the lungs. The oxygen of the atmosphere goes into the blood and the carbon dioxide produced in the body passes out of the blood. This exchange is determined by the partial pressure of each gas. In accordance with a fundamental law of physics, gases diffuse from regions of higher pressures

to those of lower pressures. In the lungs the partial pressure of oxygen is higher than in the blood; thus oxygen diffuses from lungs to blood. The reverse is true for carbon dioxide. At high altitudes, the partial pressure of oxygen is so low that little diffusion can take place. The result is that not enough oxygen can get into the blood and not enough is supplied to the brain and other organs of the body. This condition is called *anoxia.*

7. Mechanics of breathing.—*a.* The flow of gases to and from the lungs is a mechanical process. A change in the chest size is caused by the action of the muscles of respiration. The movements of the diaphragm are most important in this respect. Upon inspiration, the chest size is increased, the chest wall is pulled away from the lungs, creating a negative pressure, and the lungs are pressed from above by atmospheric pressure thus causing them to expand. This difference in pressure allows air to enter the lungs. Upon expiration, the muscular forces holding the chest at its increased size are relaxed and the chest cage becomes smaller in size, thus reducing the negative pressure within the chest. This pressure of the chest wall and diaphram on the lungs then forces the air out. It can be said that expiration is a passive act; while inspiration is an active act, as it requires muscular contraction. (See fig. 3.)

b. Breathing is under the control partly of voluntary, but mainly of involuntary, mechanisms. Certain muscle-nerve reflexes partially control respiration, but by far the greatest control is exerted by nervous impulses from a lower region of the brain called the *respiratory center.* The respiratory center is extremely sensitive to chemical changes in the blood, especially changes in carbon dioxide content.

8. Exchange of gases in the lungs.—*a.* The exchange of respiratory gases between the blood and the air in the lungs, and between the blood and the tissues, follows those physical laws which govern the behavior of gases in general.

b. Air, consisting of nitrogen, oxygen, other gases, and moisture, passes through the nose and mouth, down the windpipe or trachea and through its many branches, in order to reach all parts of the lungs.

c. The lungs consist of myriads of minute sacs or pouches called alveoli, which are extremely thin and delicate and look like bunches of grapes. Their function can be compared to the fins of a radiator. (See fig. 4.) If these membranes were spread out, they would cover an area the size of a tennis court. These microscopically thin membranes are interlaced with capillary blood vessels. It is in this large area that the air is closest to the blood, and it is here that the exchange of gases is made, which is of utmost importance to the body. Actually, the blood remains in the capillaries of the lungs about 1 or

2 seconds, and in this short time the exchange of gases is accomplished.

d. The main purpose of respiration is to supply oxygen to the tissues and to eliminate the carbon dioxide formed. But carbon dioxide, although a waste product, performs a very useful and important

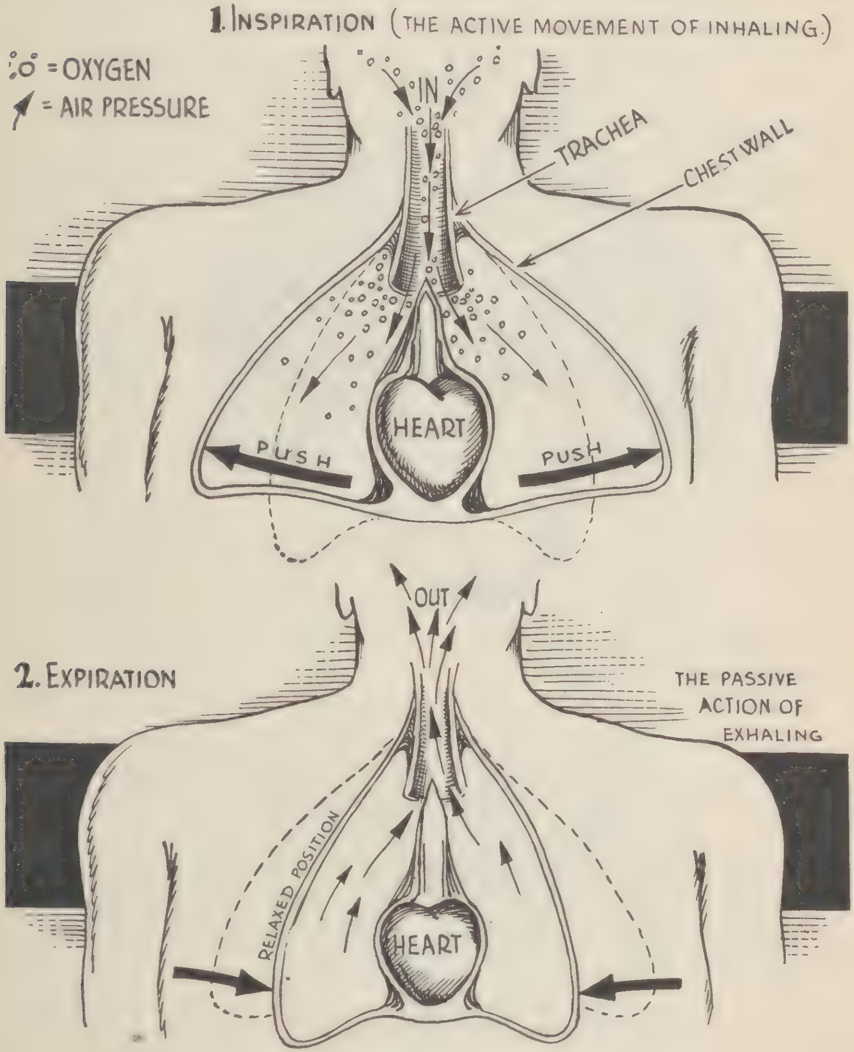

FIGURE 3.—Mechanics of breathing.

function in respiration, for it is the primary stimulant to the respiratory center. Thus, when the blood is rich in carbon dioxide, the respiratory center is stimulated and breathing becomes deeper and more rapid. This increases the amount of carbon dioxide eliminated.

When enough carbon dioxide is eliminated and the amount in the blood is back to normal level, respiration becomes normal again. Conversely, a subnormal amount of carbon dioxide in the blood going to

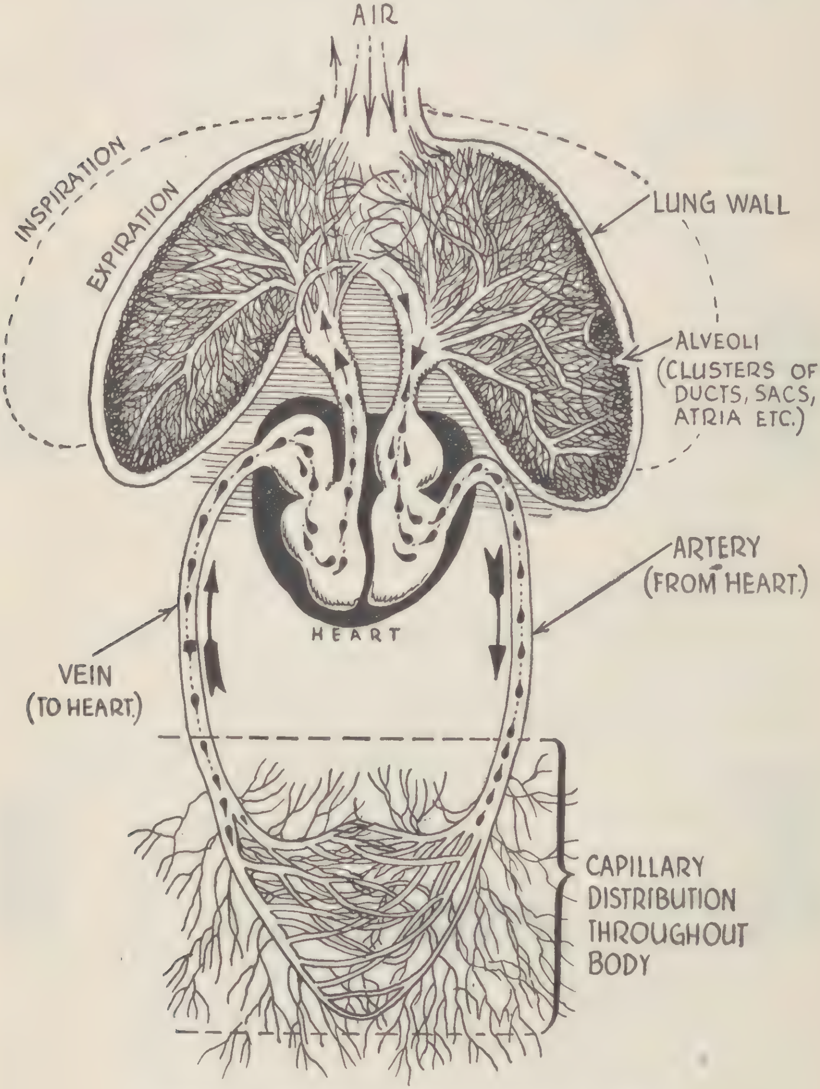

FIGURE 4.—Simplified diagram of circulatory system.

the respiratory center causes a depression of this center and breathing becomes more shallow or slower, or may even stop altogether, until sufficient carbon dioxide accumulates in the blood to stimulate the center again.

e. On ascent to high altitudes, *hyperventilation* takes place when breathing is too rapid or deep. Hyperventilation means breathing deeper and more rapidly than normal. In the rarefied atmosphere where the partial pressure of oxygen is lower, hyperventilation only serves to throw off excessive amounts of carbon dioxide. This is not desirable.

(1) A simple experiment to prove this subjectively is for the reader to stand up and take deep, exaggerated breaths. After a few minutes he will have a light-headed feeling, then sensations of fainting and dizziness, after which numbness and tingling of the hands and feet will set in. If he keeps up the deep breathing, collapse will occur.

(2) Whether at 5,000 feet or 35,000 feet, hyperventilation or forced breathing is never the complete answer to lack of oxygen or lack of air. Breathing more deeply than normal or faster than normal will not make up for any deficiency in the atmosphere. It is better to let breathing be normally controlled by the reflexes instead of trying to control it consciously.

f. Only the oxygen fraction in air is important for human respiration. The nitrogen and other chemically inactive gases not utilized are inhaled and exhaled in the same quantity. Their complete absence, as when pure oxygen is breathed, produces no effect on the human organism.

g. Water vapor tension in the lungs plays a most important part in the problems of high-altitude flying. Water, when exposed to air, tends to evaporate, that is, part of the water turns to vapor or a gas which mingles freely with the other gases in the air. The force exerted by the particles of water in the atmosphere is called the vapor tension.

(1) The essential characteristic of water vapor tension is that it is affected by temperature only, and not by pressure. All air in the body, especially the air taken into the lungs, is saturated with water vapor at a temperature of 37° C. (98.6° F.) at which temperature the water vapor tension is 47-mm of mercury. This is constant at all times, regardless of altitude, unless a fever develops or a person freezes to death.

(2) By applying the law of partial pressure in reverse, it can be shown that 47/760ths is 6.2 percent and, therefore, the air in the lungs must consist of 6.2 percent water vapor by volume at sea level. At 18,000 feet, the ratio would be 47/380ths which is equivalent to 12.4 percent of water vapor. The higher the altitude, the greater the proportion of space in the lungs occupied by water vapor. At 38,000 feet it will be 31 percent. This leaves less and less room for oxygen,

which is essential to the body. This "dog-in-the-manger" behavior of water vapor in the lungs is a very important factor in limiting the altitude which man can safely reach.

9. Red blood cells.—*a*. The red blood cells are the carriers of oxygen in the human body—the transport system of oxygen. In the red blood cells the oxygen combines with the red blood pigment (hemoglobin). The amount of oxygen carried in the blood is in proportion to the partial pressure of oxygen. When the partial pressure of oxygen in the lungs drops, the blood takes up less oxygen. This is the cause of altitude sickness so often occurring in the mountains. However, after several days at the same high altitude, the number of red blood cells increases so that the carriers may compensate for their lessened oxygen load which was caused by the decrease in the partial pressure of oxygen.

b. Airmen do not ordinarily become acclimated because they do not live at high altitudes long enough for such adjustments to take place.

10. Arterial oxygen saturation.—At ground level, the blood is approximately 95 percent saturated with oxygen. This is the normal arterial oxygen saturation.

a. Lowering the arterial saturation to 85 percent will usually affect the psychological reactions of the airman without his being aware of it. Frequent errors in judgment may be made. Navigation problems became increasingly difficult to solve. Lowering of arterial saturation is even more serious at night for the slightest degree of oxygen lack will greatly reduce ability to see in the dark. It is for this reason that all flyers on night missions are advised to use oxygen from the ground up.

b. A further lowering of the arterial saturation to about 80 percent shows even greater effects; tremor of the hands may appear, errors in judgment are frequent, and thinking and memory are clouded.

c. An arterial saturation of 75 percent is approaching the danger zone. Even while a person is resting, respiration is increased. The symptoms mentioned in *a* and *b* above are evidenced, but to a more marked degree. Fainting is frequent when pain or fear is encountered.

d. An arterial saturation of 70 percent is approaching the limit of human tolerance. Even the slightest exertion is difficult and often leads to fainting. All of the other symptoms mentioned in *a*, *b*, and *c* above become exaggerated.

e. When the arterial saturation decreases to about 60 percent, coordination is lost, writing loses either legibility or intelligibility, often both. It is almost impossible to do any work; vision is faulty; and unconsciousness soon occurs.

11. Circulatory system.—The responses of the circulatory system to changes in altitude are much more complicated than those of the respiratory system. Pulse rate and blood pressure do not increase greatly from ground level up to 10,000 feet while breathing air, or up to 38,000 feet while breathing pure oxygen. When an altitude is reached at which the saturation of arterial blood with oxygen decreases appreciably, an increase in both pulse rate and blood pressure occurs. This indicates an attempt to increase the output of blood by the heart. Emotional factors, even without this condition, may have a much greater effect upon pulse rate than variations in altitude.

Section III

EFFECTS OF PRESSURE CHANGES ON THE HUMAN BODY

12. Aeroembolism.—*a.* The total decrease in barometric pressure is not as great a hazard to high altitude flying as is the decrease of oxygen in the atmosphere. Due to the fact that the tissues of the body contain 70 percent water and the rest consists of substances which, like a fluid, cannot be markedly compressed, there is no noticeable expansion of the body tissue or of the blood vessels despite the decrease in atmospheric pressure. But the effect on the gases contained in the blood and other tissues is different and follows the laws governing the behavior of gases.

b. Aeroembolism ("bends," and "chokes," or decompression sickness) is produced by exposures to low atmospheric pressure (high altitude) and is characterized by the formation of bubbles, mainly nitrogen, in the tissues, blood, and other fluids of the body. It rarely occurs below 30,000 feet and is similar to the "bends" of deep-sea divers. The physiologic explanation for aeroembolism is as follows:

(1) Almost 79 percent of the atmosphere is made up of nitrogen, a chemically inactive gas. This goes freely into solution in the blood and is in constant equilibrium with the atmosphere.

(2) Unlike carbon dioxide and oxygen, which are chemically active and are used up in the body, nitrogen is not used and remains in the body unless it can leave through the lungs. At rapid elevation to high altitude, due to decreased partial pressure, the same thing happens as occurs when the top is removed from a bottle of pop or charged

water. In the manufacture of charged water, carbon dioxide is forced into the bottle under pressure and the bottle is capped. The gas goes into solution. When the cap is removed, the gas comes out of solution because of the lower pressure of the outside air (Henry's law of gases). Similarly, nitrogen is dissolved in the tissues and fluids of the body under one atmosphere of pressure. As the aviator ascends, the atmospheric pressure decreases and the nitrogen begins to come out of solution and forms bubbles, just as carbon dioxide does when the charged water bottle is opened.

c. Nitrogen bubbles will appear in many tissues of the body but the most common locations are around the joints and in fatty tissues. The factors influencing the symptoms are:

(1) Rate of ascent.

(2) Altitude attained.

(3) Duration of exposure to the altitude.

(4) Individual susceptibility.

(5) Physical activity at high altitudes.

d. Symptoms of aeroembolism are varied as to location and severity.

(1) Pain in and about the joints may be mild at first but often becomes so severe that it is intolerable. The larger joints, such as those of the knee and shoulder, are most frequently affected. Other joints commonly involved are the small joints of the hands, wrists, and ankles.

(2) Pulmonary symptoms, referred to as "chokes," probably are caused in part by blocking of the vessels of the lungs by myriads of small bubbles. At first there is a burning sensation underneath the breast-bone. As the condition progresses the pain becomes more severe, may be stabbing in character and is markedly accentuated by the person's taking a deep breath. There may be an uncontrollable desire to cough, but the cough is ineffective and nonproductive. Finally, there is a sensation of suffocation; breathing becomes more shallow and there is syanosis due to anoxia (bluish discoloration of the nails, lips, and skin). Descent is imperative at this point. Fatique, weakness, and soreness of the chest may persist for several hours after descent to ground level. No permanent injury has ever been reported as a result of high altitude flights.

(3) Tingling and itching of the skin, as well as cold and warm sensations in the skin, are also manifestations which are probably caused by bubbles in the central nervous system. Sometimes cold and warm sensations of the eyes and eyelids occur. Occasionally a red rash may appear on the skin. These conditions disappear quickly,

seldom lasting more than 1 or 2 hours and rarely as long as 1 or 2 days.

(4) Blurred vision occurs on rare instances during or after descent. No permanent after effects have been known to occur.

(5) Pains similar to the pains of neuritis (inflammation of a nerve) occasionally occur. On very rare occasions, temporary partial paralysis of an arm or leg that has been aching will set in. This is always relieved during descent.

e. Susceptibility to aeroembolism is relatively high and varies with each individual. Within a period of 5 days, 200 flyers made a total of 584 consecutive ascents to 35,000 feet in a low-pressure chamber, at a rate of ascent of 1,000 feet per minute, and remained there for 3 hours. Eighty-seven descents were necessary. There were 75 cases of joint pains, seven cases of "chokes," three cases of abdominal pains due to gas, and one case each of ear distress and hyperventilation (abnormally rapid and deep breathing).

f. Due to increased demands for high altitude flying at 35,000 feet or more during tactical operations, it is obvious that the disabling of one member of a combat crew may mean the failure of the mission. It is necessary to determine each airman's tolerance to high altitudes before he is assigned to such a mission.

g. Evidence indicates that age, weight, and physical condition are relatively important factors in aeroembolism. It appears that age or excess weight makes an airman more susceptible to "bends." The best way to increase tolerance for high altitudes is by the proper maintenance of physical fitness.

h. Where the tactical situation permits, relief from symptoms which are severe should be immediate. This relief can be brought about by descent to low altitudes (called recompression). Most symptoms disappear at 25,000 feet, although chest symptoms and fatigue may persist several hours after return to ground level. Permanent injury never has been authentically reported. If collapse and unconsciousness result from aeroembolism, the patient, if possible, should be placed in a horizontal position with the legs elevated and oxygen should be given. If breathing has ceased, artificial respiration should be carried out.

i. Prevention of aeroembolism can be aided by breathing pure oxygen for a period of 45 minutes before ascent and continuing to breathe it from the ground up. Breathing pure oxygen eliminates nitrogen from the body by gradually reducing the partial pressure of the nitrogen in the lungs to zero.

j. Although dramatic and highly interesting, the symptoms of aeroembolism are readily relieved upon descent to lower altitudes and are

of small significance as compared to the effects of anoxia (see sec. IV), which costs the lives of flying crew members daily due to poor oxygen discipline.

13. Air spaces in the body affected by low atmospheric pressure.—The body has three air spaces which are affected by sudden changes in altitude:

a. The middle ear.

b. The sinuses.

c. The intestinal tract.

14. Middle ear.—*a.* The middle ear is like a box. One wall is the ear drum, and the other walls are bone. In this box is a chain of three bones which transmit vibrations from the drum to the real organ of hearing which is the inner ear.

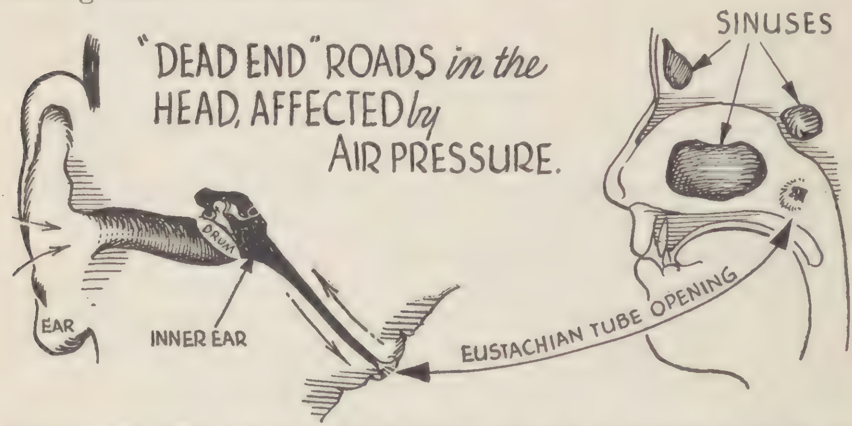

FIGURE 5.—Simplified diagram of the Eustachian tube and its openings to the ear and sinuses.

(1) The middle ear connects with the outer air by a passage which ends in the back wall of the throat. This passageway is called the Eustachian tube. (See fig. 5.) The throat end of the Eustachian tube is a sort of flutter valve which allows air to pass outward easily, but resists the passage of air in the opposite direction. It is due to this flutter-valve action that on ascent air leaves the ear easily. Sometimes the ear seems full and then there is a click as the air passes out. It is during descent that the changes in pressure of the air in the middle ear do not occur automatically.

(2) Marked pain and perhaps rupture of the eardrum will result unless the pressure between the outside air and that in the middle ear is equalized. (See fig. 6.) By swallowing, yawning, or holding mouth and nostrils and gently blowing, relief can be obtained. This is because the same muscles which close the nose from the throat by lifting the soft pallet against the rear openings of the nose also act to pull open the ends of the Eustachian tubes.

b. A rapid descent from 30,000 feet to 20,000 feet often will cause no discomfort; however, a similar descent from 15,000 feet to 5,000 feet will cause great distress because the change in barometric pressure is much greater in the latter case. (The change in pressure from

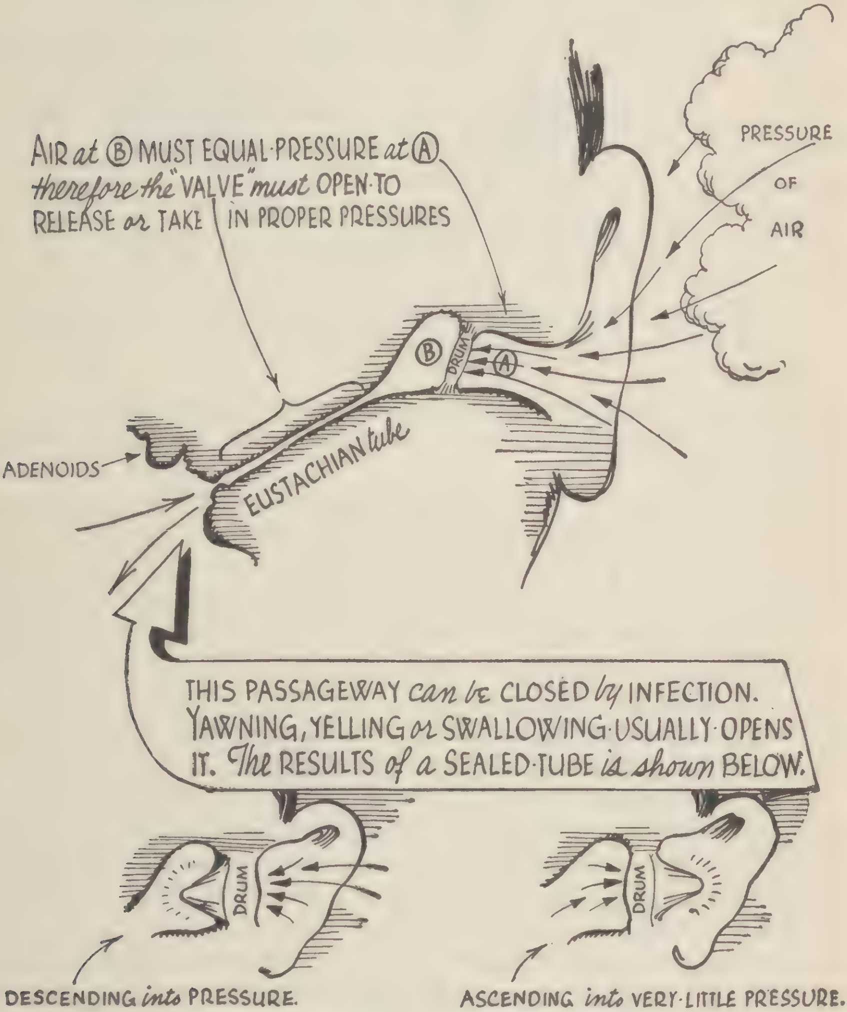

FIGURE 6.—How middle ear is affected by pressure.

30,000 feet to 20,000 feet is 2.4 pounds per square inch. The change in pressure between 15,000 to 5,000 feet is 4 pounds per square inch.) If pressure does not equalize after a rapid descent and marked pain persists or increases, then ascent should be made to the point where the pain decreases. After that a slow descent should be made.

c. When an individual has a head cold the Eustachian tube is swollen by inflammation and the passage is constricted. This condition may interfere with ventilation of the middle ear so that on ascent and descent the pressure in the middle ear may not be equalized with the atmospheric pressure. This may result in an ear condition known as *aero-otitis media.* The symptoms are pain and deafness. In mild cases this clears up in a few days. In severe cases it may take several weeks.

d. To rupture the eardrum usually requires a fall of at least 22,000 feet without clearing the ear. The first sensation is acute pain like being hit on the side of the head with a board. If the eardrum heals without infection and if the middle ear does not fill with scar tissue, hearing will be unimpaired. Healing is usually complete and uneventful.

e. The following precautions should be taken to avoid aero-otitis:

(1) Don't fly while suffering with a cold unless it is absolutely necessary.

(2) If it is necessary to fly, see your flight surgeon.

(3) Ascend and descend slowly, if possible. Don't go higher than is necessary.

(4) Keep your ears open by swallowing frequently or by any other means which is effective.

15. Sinuses.—*a.* The nasal sinuses connect with the outer air by passages which end in the nose. The sinuses are air-filled, relatively rigid bony cavities lined with mucous membrane. They lighten the skull and act as resonators. Two of the sinuses are situated within the bones of the forehead, one within each cheek bone, and two in the bones just back of the root of the nose (see fig. 7). The sinuses present the same conditions during flight as does the middle ear.

b. The sinuses cause pain only when their openings are obstructed, thus preventing equalization of pressure with the outside air. Such obstruction is usually caused by mucus from the nose and throat, infectious discharges, or, most frequently, by swelling of the mucous membrane which occurs during a cold. As with the ear, air leaves the cavities with ascent to altitude. With descent to lower altitudes and therefore greater pressure, air flows back into the sinuses sometimes carrying with it any infected material that may be there. If the pressure in the sinuses cannot be equalized with the atmospheric pressure, the sinuses may become very painful.

c. Unless it cannot be avoided, flying personnel should not fly while suffering from a cold. The symptoms and duration of difficulty with sinuses as a result of flying are generally more severe than aero-otitis. The same recommendations as for aero-otitis are to be followed for this condition.

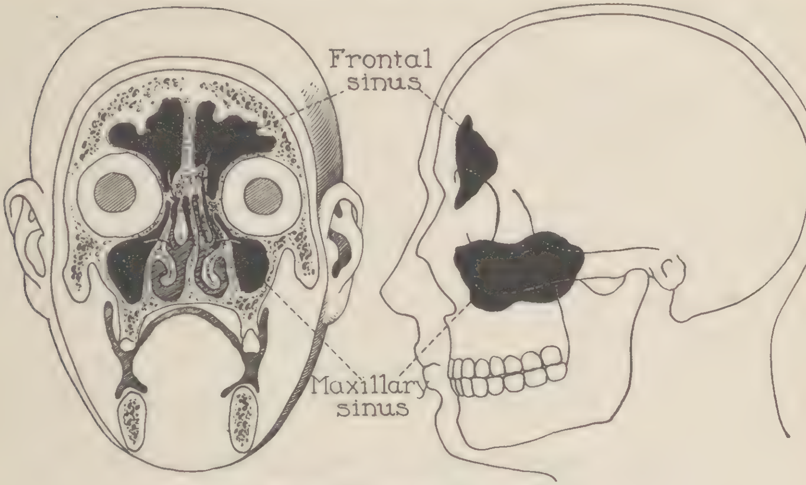

FIGURE 7.—The paranasal sinuses.

16. Intestinal tract.—*a.* The gases in the stomach and intestines act in accordance with Boyle's law (the smaller the space in which a given amount of gas is held, the greater its pressure), with the exception that they are saturated with water, causing even greater expansion with a decrease in atmospheric pressure. Relief is usually obtained by belching and the passing of flatus. If relief is not obtained, there may be considerable discomfort. At 18,000 feet gases are more than doubled in volume; at 27,000 feet they are more than tripled and at 33,000 feet more than quadrupled.

b. The prevention of gases in the stomach and intestines is usually an individual matter, although several types of food are almost universally gas-forming, such as dried beans, cooked cabbage, onions, and sauerkraut. These foods should be avoided before high altitude flying. Other helpful factors are daily exercise, regular evacuation of the bowels, eating at regular hours, and avoidance of overeating.

17. Pressure suits, pressure cockpits, and pressure cabins.—*a.* To protect flyers from the hazards of high altitudes, three devices, somewhat similar in principle, have been developed: the pressure suit, the pressure cockpit, and the pressure cabin. All operate on the principle of maintaining air in an inclosed space at a higher pressure than exists at the altitude at which the flight is being conducted.

b. The advantages of the pressure suit are:

(1) Its weight and the amount of equipment required for its maintenance are relatively small in contrast to that of pressure cockpits and pressure cabins.

(2) It can be used in different types of airplanes without change in construction.

(3) Because of its smaller size it is not as vulnerable to puncture by gunfire.

c. The disadvantage of the pressure suit is that it handicaps the maneuverability of the wearer. Since the joints must be airtight, the suit is fairly rigid, increasing the difficulty for the pilot and others who are called upon to make rapid and exact movements.

d. Pressure cockpits and pressure cabins operate in the same manner as pressure suits, except that the space to be put under pressure is larger. For that reason the problems of both are the same and they will be considered under one heading—pressure cabins. Pressure cabin aircraft have the following advantages:

(1) They permit flying to high altitudes without the supplemental use of oxygen and the discomfort of using oxygen masks while on a long mission.

(2) They permit flyers to fly well over the 40,000-foot ceiling to which they are now limited, even while using oxygen.

(3) They prevent aeroembolism, for the body is not exposed to the effects of extremely low barometric pressure.

(4) They permit controlled ventilation and heating.

e. The disadvantages of pressurized aircraft cabins are:

(1) Increased weight and bulk in the necessary construction to withstand pressure.

(2) Maintenance of additional equipment.

(3) The danger of sudden decompression.

f. The greatest danger of the pressure cabin aircraft is puncture of the pressurized compartment by enemy gunfire. This would cause an almost instantaneous loss of pressure which would result not only in aeroembolism, but also anoxia and possible injury to the ears and other organs of the body. Experiments show that the mean period of useful consciousness when the use of oxygen is discontinued is about 1 to 1½ minutes at 30,000 feet, ½ to 1 minute at 35,000 feet, and less than ½ minute at 40,000 feet. To prevent this it is suggested that oxygen equipment be available for immediate use by flight personnel at all crew stations.

SECTION IV

ANOXIA

18. Definition.—The commonly accepted definition of *anoxia* is oxygen deficiency or an intermediate degree of oxygen lack. The de-

gree of anoxia depends upon the amount of reduction below the normal value of the partial pressure of oxygen in the air sacs of the lungs. The tactical efficiency of an airman at high altitude is determined by the amount of oxygen available to the cells of his body, particularly the cells of the brain and spinal cord. Anoxia can be caused by one of the four following conditions, or a combination of them:

a. The most common is a low concentration of oxygen in the air breathed. This is the type of anoxia encountered at high altitudes when no oxygen equipment is used, or when the equipment fails. It is the most important type as far as the aviator is concerned.

b. The inability of the blood to transport enough oxygen. This may result from anemia arising from excessive loss of blood, or from a condition of the blood in which the number of red blood corpuscles is greatly reduced.

c. The inability of oxygen to get into the blood cells or, once it is in the blood cells, to get into the tissues and supply them. This is due to poisons. Carbon monoxide is responsible for the first condition since it has an affinity for the hemoglobin of the blood cells 200 times stronger than oxygen. (See sec. VII.) When other poisons, such as alcohol and cyanide, are present there appears to be sufficient oxygen in the blood cells, but it remains there because the tissues are unable to take it up.

d. The quantity of oxygen delivered by the blood to the cells depends not only on the oxygen-combining capacity of the blood but also on the rate of flow of the blood (so-called minute-volume or amount of blood per minute). This is increased in a healthy person exposed to oxygen deficiency because of the increased circulation rate, but it may be decreased by anything which slows the circulation of blood in the body as a whole or in any part.

19. Symptoms.—*a.* The most dangerous feature of oxygen lack is that it produces disabling, even fatal, effects without the slightest warning or knowledge.

b. Vision is impaired quickly by oxygen lack. Especially is this true of night vision, which may be considerably reduced at altitudes as low as 6,000 feet. This is due to the special sensitivity of the eye to oxygen lack. (See sec. XI.)

c. At altitudes up to 8,000 or 10,000 feet few effects of oxygen lack are observed.

d. From 10,000 feet to 14,000 feet the body is forced to make definite adjustments for the purpose of compensating for the low oxygen tension. Although respiration is increased and physical activity at this altitude will result in actual panting, it is rarely noted. Remaining at this altitude for any length of time causes mental and muscular

fatigue. There is a readjustment of the heart action and the circulation, as witnessed by an increase in pulse rate.

e. Above 14,000 feet, an even more definite reduction of efficiency occurs, although the flyer is usually unaware of it. The following are the symptoms noted; their onset and severity are directly increased with higher altitude and longer exposure to that altitude:

(1) In addition to the impairment of night vision, other changes in the eye occur, such as double vision, loss of depth perception, and eye fatigue.

(2) Mental processes are slowed down. Calculations such as those required of navigators or bombardiers may become unreliable. Memory is impaired. Critical judgment becomes faulty.

(3) Tremor and even paralysis may develop. Muscular coordination is bad. Handwriting may become scarcely legible and smooth aerobatics or close formation flying is difficult. One of the most important of physical signs is a general cyanosis (bluish discoloration of face and fingernails).

f. Recovery from anoxia is rapid when sufficient oxygen is applied. A person may be brought from the edge of unconsciousness to full recovery within 15 seconds. It is important that oxygen be given promptly. Headache is a common result after a severe, prolonged period of anoxia. However, permanent disability arising from anoxia is rare if the exposure is brief. The greatest danger in anoxia is that the symptoms develop without the individual's recognizing them. As a result, unconsciousness may occur before the individual becomes aware of the fact that he is anoxic.

20. Degrees.—*a.* The condition of a man depends on the percentage of saturation of the blood with oxygen, and this in turn is dependent on the partial pressure of the oxygen in the air he breathes.

(1) At sea level, the barometric pressure is 760-mm of mercury. Since the atmosphere is 21 percent oxygen, the partial pressure of oxygen is approximately 160-mm of mercury. Under these conditions the blood is about 95 percent saturated with oxygen. This is more than ample to sustain all normal tissue functions.

(2) At 18,000 feet the barometric pressure is 380-mm of mercury—exactly one-half that at sea level. The partial percentage pressure of oxygen is also half that at sea level or about 80-mm of mercury. Under these conditions the blood will be only about 70 percent saturated with oxygen, which is a dangerous condition.

(3) Above 18,000 feet, the flyer cannot maintain consciousness for very long periods of time without the use of supplemental oxygen. This is due to the fact that the partial pressure of oxygen in the atmosphere becomes too low to maintain enough oxygen in the blood.

(4) It will be assumed that the flyer using oxygen continues to ascend; at 27,000 feet the pressure is only one-third that of sea level pressure and the partial pressure of oxygen in the air is 53-mm of mercury.

(5) At 33,000 feet, barometric pressure is only 196, and the oxygen partial pressure is 39-mm of mercury in the air.

(6) At 50,000 feet the total barometric pressure is only 87-mm of mercury. Within the lungs, carbon dioxide has a partial pressure of 40-mm of mercury. The partial pressure of water vapor at body temperature is always 47-mm of mercury under normal conditions. Thus, within the lungs there is a total combined pressure of carbon dioxide and water vapor of 87-mm of mercury. At approximately 50,000 feet, therefore, all the space within the lungs would theoretically be occupied by carbon dioxide and water vapor.

(7) The critical point is at approximately 33,700 feet, where 100 percent of oxygen is just enough to maintain the blood within the range of customary sea level saturations. The use of a pressure suit or a pressure cabin or pressure helmet is the only way it is possible to go to higher altitudes and still maintain sea level conditions of the blood.

b. Duration of exposure is a very important consideration. The highest tolerable altitude for exposure lasting longer than a very few minutes are 19,000 to 20,000 feet while breathing air, and for a few minutes, about 44,800 feet, when breathing 100 percent oxygen. Most men can tolerate an altitude of 18,000 feet for ½ hour without oxygen, but they will be in a befogged state and may collapse. The same men will remain conscious for a few minutes at 25,000 feet, but there is a greater probability of collapse. At 35,000 feet, death will probably occur in 10 to 15 minutes after loss of consciousness.

21. Summary and conclusions.—*a*. The brain reacts to lack of oxygen more markedly than does any other organ in the body. Like the results of alcohol, manifestations of anoxia are insidious. The airman loses his capacity to judge to what extent he is already suffering from altitude sickness and this leads him to neglect to employ oxygen. Ofter a person in this stage of anoxia is like someone under the influence of alcohol; he displays an exaggerated mood of confidence and ability in his own judgment, whereas, on the contrary, he is beginning to lose control of his faculties.

b. It has been proved that above 15,000 feet most persons are less capable mentally. There are on record hundreds of cases of peculiar reactions due to anoxia. The Frenchman, Tissandier, in 1875 luckily escaped with his life after a balloon ascent to 26,000 feet, al-

though his two companions were dead; recently a reconnaissance pilot who thought he had accomplished his mission, was startled to learn, upon having his films processed, that he had flown over his own lines instead of the enemy's taking pictures at 20,000 feet.

c. There is no excuse for anoxia if the flyer has been instructed properly and understands the use of his equipment. There are two simple and important rules to remember:

(1) Use oxygen from the ground up on all night missions.

(2) Use oxygen at all times above 10,000 feet.

Section V

PARACHUTE DESCENTS

22. Physiological effects of parachute descent.—*a.* It has long since been proved that a free fall in space results in neither unconsciousness nor death. The fear of jumping may result in fatal accidents if the airman should choose to stay with his disabled airplane and risk a crash rather than use his parachute. This impulse is readily understood, for fear of falling is instinctive in man. Most airmen taking to their parachutes are compelled to overcome their fears of even a short free fall and to resist the temptation to pull the rip cord too soon.

b. The physiological effects of parachute descent vary greatly in different persons. The methods for avoiding most of these dangers have been taught to flying personnel during their various periods of training. Only those pertinent to this manual will be discussed. The most important factors appear to be—

(1) Fear and excitement springing from an instinctive dislike of falling.

(2) Nervous and mental conflict when thinking of the hazards, such as fear of fouling the parachute in the airplane, possible parachute defects, or dangers of landing, particularly at night.

(3) Effects upon the senses when leaving the airplane and entering the atmosphere.

(4) Effects of rotation and fall upon the senses before the parachute is opened.

(5) Effects of acceleration and deceleration particularly at the time of the parachute's opening.

(6) Effects of oxygen want during descent through rarefied atmosphere.

(7) Danger of collision with other aircraft during descent.

(8) Danger of enemy gunfire during descent.

(9) Danger of impact and collision with objects on the ground when landing.

(10) Danger of being dragged by the wind.

(11) Danger of landing in water.

23. Forces acting upon the human body during parachute jumps.—*a*. The parachute is a device developed to retard the rate of fall by producing a resistance in the air. This resistance allows a rate of descent within the limits of human tolerance at the time of impact with the earth's surface.

b. In parachute jumps there are three forces which have important physiological effects upon the human body:

(1) Acceleration during the free fall before the parachute is opened.

(2) Deceleration (retardation) when the parachute opens.

(3) Deceleration (impact) upon making contact with the earth's surface.

c. These forces must be kept within the limits of human tolerance as follows:

(1) While traveling at a great rate of speed, parts of the body cannot be exposed without danger. When an airplane is traveling at military speed, if an arm were held out, it would probably be broken. Therefore, it is highly important that speed be reduced before jumping from an airplane. For a short period of time after jumping the parachutist will be traveling at the same velocity and in the same direction as the airplane. If the parachute is opened too soon, the flyer may be injured by the sudden deceleration. There is also the possibility that the terrific strain on the shrouds of the parachute may tear them loose. A free fall is recommended until the velocity imparted by the airplane is diminished.

(2) A man equipped with a closed parachute pack will fall at a rate of approximately 120 miles per hour. At this terminal velocity of fall the parachute functions smoothly without any undue stress on the man or equipment.

(3) Parachutes are designed to land a person at a speed which is the equivalent of jumping from approximately a height of 10½ feet. However, this condition varies because of atmospheric conditions, vertical air currents, and the weight of the parachutist.

24. Parachute jumps at high altitudes.—*a*. A most important question arises in getting out of an airplane at high altitudes. The critical period is that time between detachment from the ship's oxygen line, jumping clear of the airplane, and the opening of the parachute.

b. It is obvious then if the parachute is opened much above 35,000 feet and the parachutist is without oxygen, he will undoubtedly become anoxic. (See par. 17*f*.) Despite this fact, missions and combat take place at this and greater altitudes, hence the necessity of furnishing some method of permitting an escape to be made at such heights.

c. There are two methods of making a safe parachute jump from high altitude: the use of a "bail-out bottle" with an open parachute and the free-fall descent.

d. The bail-out bottle is a small oxygen cylinder designed to be carried in a pocket of the flying suit. The oxygen is provided through a pipestem. An 8-minute supply of oxygen is available. This is enough to permit safe descent from 35,000 feet in an open parachute. However, to use the bail-out bottle, the oxygen mask must be removed and the pipestem placed between the teeth. The removal of the mask exposes the face to possible freezing during descent through the upper atmosphere.

e. The walk-around bottle is found in multiplace aircraft, such as a bomber. It is used without removal of the mask, but holds less oxygen than the bail-out bottle. The flyer holds his breath while he disconnects his oxygen mask hose from the airplane's oxygen line and connects it to the walk-around bottle. It is designed primarily to facilitate movement in the airplane, but it can be used in emergency as a bail-out bottle. (See fig. 20.)

f. The time for both the free-fall descent and open parachute descent from 30,000 feet is shown in figure 8. The same data concerning descent from 40,000 feet are shown in figure 9. The free-fall descent has the following advantages:

(1) The parachute will not open too soon and become entangled with the airplane.

(2) Sufficient time elapses for the velocity of the parachutist to slow down to the rate of fall of approximately 120 miles per hour. Thus the parachute will not be torn, nor will the strain of the opening be too great for the parachutist.

(3) The parachutist presents a difficult target for the enemy to fire on.

(4) In a relatively short time the parachutist is in a safe altitude for breathing air without supplemental oxygen.

g. Simulated free-fall parachute descents in the low-pressure chamber have shown that descent from an altitude of 40,000 feet can be carried out without loss of consciousness and without supplementary oxygen equipment. It is necessary to observe the following precautions:

(1) Take several deep breaths of oxygen prior to the start of descent.

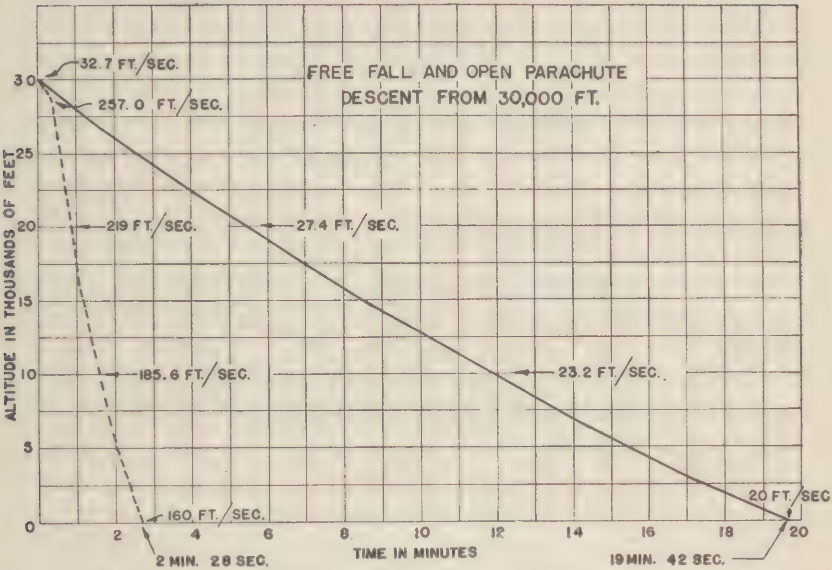

FIGURE 8.—The dotted line represents the speed at which a man falling without a parachute would reach the earth from an altitude of 30,000 feet. The solid line represents the time in which a man with a parachute, descending from the same height, would reach the earth. Note changes in rate of speed in each case. Note that if a flyer falls free, without opening his parachute until he reaches lower altitudes, he will quickly escape the extreme cold and lowered oxygen tension of the high altitudes.

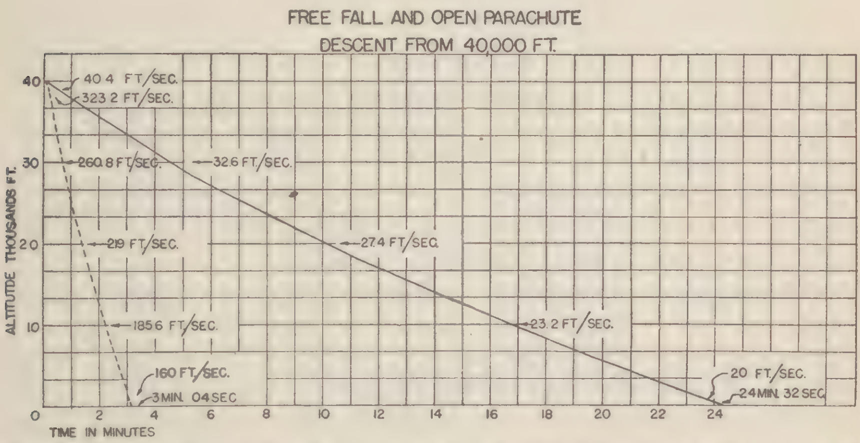

FIGURE 9.—Chart showing that if a man falls free from an altitude of 40,000 feet, he will reach the earth in slightly more than 3 minutes; if he falls free from 30,000 feet (fig. 8), he will reach the earth in 2 minutes, 28 seconds.

(2) Hold the breath for at least 30 seconds (preferably as long as possible).

h. If the two conditions in *g* above are not met, a brief period of unconsciousness will ensue, but this period of unconsciousness, except in the case of an injured man, will most likely be so short that there will be plenty of time for the opening of the parachute. It is doubtful that the man would even know he had been unconscious because of lack of oxygen.

(1) In a series of laboratory tests in which the condition of loss of consciousness from altitudes of 36,000 feet was simulated, the subjects fell free and all recovered sufficient consciousness to pull the rip cord between 25,000 and 2,200 feet, the average pull being made at 14,100 feet.

(2) Rupture of the eardrums may occur unless the ears are cleared before falling below 15,000 feet and kept clear below this level. Although rupture of the eardrums is painful, it is a minor factor in such a vital matter.

Section VI

OXYGEN EQUIPMENT

25. General.—*a.* The use of oxygen in aviation has raised the absolute ceiling, physiologically speaking, from 18,000 to 40,000 feet. It has also placed a heavy responsibility on officers who are responsible for teaching flying personnel the narrow dividing line between life and death at extreme altitudes. As has been pointed out, there is no danger at altitudes up to 40,000 feet when the flyer is provided with perfectly functioning oxygen equipment.

b. Flying personnel must be disciplined in the use of oxygen equipment as carefully as ground personnel are disciplined in the use of gas masks. For that reason a brief general survey is given of the two main methods in use at present in the Army Air Forces. Further information can be gathered from the specific Technical Orders covering this field and from the unit oxygen officer.

c. There are two essential requirements of a good oxygen system:

(1) Economy in weight.

(2) Safety and reliability under extreme conditions of temperature, pressure, acceleration, or combat operation.

26. Continuous-flow oxygen system.—*a.* The continuous-flow or free-flow oxygen system is the logical development from the old pipestem method. The pipestem is nothing more than a rubber tube through which pure oxygen flows. The tube is held in the mouth between the teeth, and the oxygen is breathed in this uncomfortable manner.

b. In most continuous-flow oxygen systems, whether pipestem or mask, the regulator is set manually to the desired altitude. It then becomes necessary for flying personnel to adjust the regulator continually upon going higher or lower for the obvious purpose of preventing anoxia and also to prevent waste of oxygen. Because of the increasing number of mechanical complexities in aircraft, this task is an additional burden to the individual concerned.

c. The pipestem was eliminated because it was unsatisfactory, especially for long missions. The next development was a mask, the type A–7, which allows oxygen to be breathed only through the nose. This was followed by the oronasal type (both through nose and mouth). A series of masks were designed, each an improvement over the last, until the type A–8 was evolved.

d. The type A–8 oxygen mask is an oronasal type. Furthermore, it permits rebreathing part of the oxygen expired from the lungs and respiratory passages, thus conserving the limited available oxygen supply (see fig. 10 ①). The mask consists of a rubber molded oronasal cover with a rigid case of phenolic compound which supports the mask and a turretlike protrusion containing a sponge rubber disk in front of the mouth. Attached to the base of the mask is a connector sleeve of phenolic compound to which is attached a flexible rubber rebreather bag provided with an oxygen intake tube. The end of the intake tube is equipped with an oxygen mask coupling fitting, which permits the mask apparatus to be attached readily, bayonet fashion, to the oxygen regulator. (See fig. 10 ②.)

e. A mixture of oxygen and previously exhaled gases is inhaled from the rubber reservoir bag. Upon exhalation, the first part of the expired air passes into the bag and, as soon as the bag becomes distended, the remaining gases pass out through the sponge rubber disk. Upon inhalation, the gases are first taken from the bag and, when the bag is depleted, an additional amount of air is drawn in from the atmosphere through the sponge rubber disk. Increasing the flow of oxygen at higher altitudes permits the flyer to breathe a richer mixture of oxygen and lesser amounts of atmospheric air.

(1) Mock-up of a low-pressure, continuous-flow oxygen system for pursuit airplanes.

Operating diagram of A–8B oxygen mask and A–9–A continuous-flow regulator.

FIGURE 10.

Several difficulties were encountered with this type of mask, but improvements were made.

f. The latest mask for use with a continuous-flow oxygen system is the type A–8B, which is standard. It is provided with a helmet suspension. However, an adapter is available for use of the mask without the helmet. The microphone is installed in the central pocket, while the two turrets, one on either side of the pocket contain the sponge rubber disks. Two disks reduce the breathing resistance and lesson the chance of freezing, which was one of the bad features of the two earlier masks of this type.

27. Precautions in use of continuous-flow oxygen system.—*a. Before the take-off.*—(1) Check the cylinder pressure. For A–6 or A–8 regulators, it should show 1,800 to 2,000 pounds; for A–9 or A–11 regulators, 400 to 500 pounds.

(2) Be sure that the valve on the high pressure cylinder is fully open. Leakage is frequent at intermediate positions, and flow may be insufficient. (See fig. 11.)

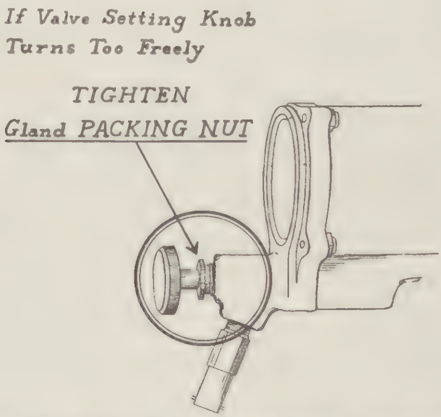

FIGURE 11.—The valve adjustment knob of the oxygen regulator of the continuous-flow system should have a fair degree of resistance against turning. If it does not, a sleeve brushed against it may change the setting. The arrow points to the gland packing nut, which can be tightened to provide the degree of resistance (of the knob) desired.

NOTE.—One source of accidents reported is failure to open the cylinder valve completely. While the regulator is closed, the slightest crack of the cylinder valve will suffice to show the cylinder pressure. Yet, when the regulator is turned on, the crack may be insufficient to supply adequate flow, so that the pressure gage falls rapidly to a low value. It is thus important to be sure the cylinder valve is fully open and to get the habit of looking down at the cylinder pressure gage after the first two or three breaths have been taken.

(3) Have rate of flow from the regulator checked every 10 days with a flowmeter, if possible; the regulators are variable in performance.

(4) Be sure the mask and the bag are securely fastened to the plastic connecting tube.

(5) Check bag for small holes. Be sure plug is in the bottom of the bag.

(6) Make certain that the sponge rubber disks are in proper position and in good condition.

(7) Know where regulator is located.

(8) Use protective shields for the exhalation turrets, if they are available.

(9) Make sure the valve adjustment knob of the regulator has a fair resistance against turning; a sleeve brushed against it may change the setting. This resistance can be increased by tightening the gland packing nut.

(10) Observe the general precautions which apply to use of any oxygen system, including the following:

(*a*) Never apply oil to any part of the oxygen equipment.

(*b*) See that all parts are free of dirt.

(*c*) Check system frequently for leaks. Pressure should maintain itself overnight with all regulators set to "off" position.

b. In the air.—(1) Be sure regulator is set to proper altitude.

(2) Check cylinder pressure occasionally.

(3) Always breathe normally; voluntary overbreathing accomplishes nothing and may be extremely dangerous.

(4) Examine sponge disks at intervals, removing ice by squeezing. Carry an extra set of sponge rubber disks, or preferably an extra mask.

(5) Above 30,000 feet, be sure that the bag is never completely collapsed during inspiration; if it is, open the regulator valve farther, no matter what the flowmeter reads.

(6) When muscular exercise is required at an altitude of more than 25,000 feet, open valve far enough to insure adequacy of oxygen supply, so that inspiration does not collapse the bag.

(7) On change of station at altitude, be sure the new cylinder valve is fully *on* and that the bayonet fitting is locked.

c. After the flight.—(1) Shut the flow valve and be sure it is tightly closed before leaving the airplane.

(2) Wash mask with soap and water, rinse well, and hang it up to dry.

(3) Never expose the mask unnecessarily to heat or sun.

(4) Never lend mask to anyone except in an emergency.

(5) Keep mask in its place. This place is in the airplane during flight.

(6) Check bayonet connection to see that small rubber seat is in place.

28. Demand oxygen system.—*a.* The demand system secures the greatest economy in the use of oxygen. It is fully automatic and provides the user with the proper amount of oxygen at all altitudes and under all conditions. As the name implies, it furnishes oxygen only upon demand. It calls for two types of equipment different from that of the continuous-flow system: the demand regulator and the demand mask. (See fig. 12.)

FIGURE 12.—Mock-up of low-pressure demand oxygen system for pursuit airplanes.

b. The demand regulator is essentially a diaphram-operated flow valve, which is opened by the suction of the user's inspiration and closed automatically when that suction ceases. It supplies the flyer with the proper mixture of air and oxygen at all altitudes every time he inhales and shuts off when he exhales. The percentage of oxygen delivered to the user increases with increasing altitude, becoming 100 percent at an altitude of about 30,000 feet. This action is completely automatic, requiring no attention from flying personnel. (See fig. 13.) The regulator is installed as a permanent fixture of the airplane. There is a demand regulator for each station in the airplane.

c. Two manual controls on the regulator are provided for use in special instances. One is labeled "Auto-mix" and the other, "Emergency." (See fig. 14.)

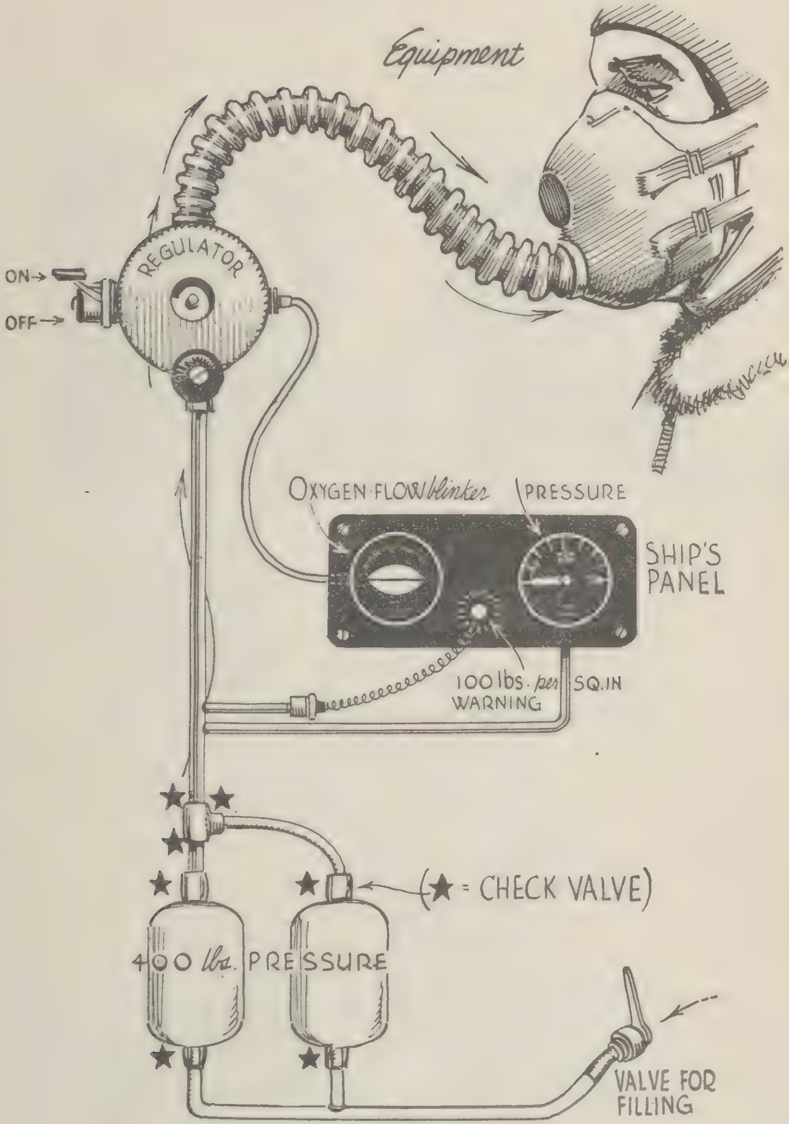

FIGURE 13.—Demand oxygen system—schematic diagram.

(1) "Auto-mix" means automatic mixing. There are only two positions—"on" and "off." The normal position is "on." When the auto-mix is "on," the regulator automatically mixes the proper amount of air with the oxygen at all altitudes. When the auto-mix is "off," the air port is shut off and no atmospheric air can be taken into the regulator. The regulator then will deliver oxygen at all altitudes.

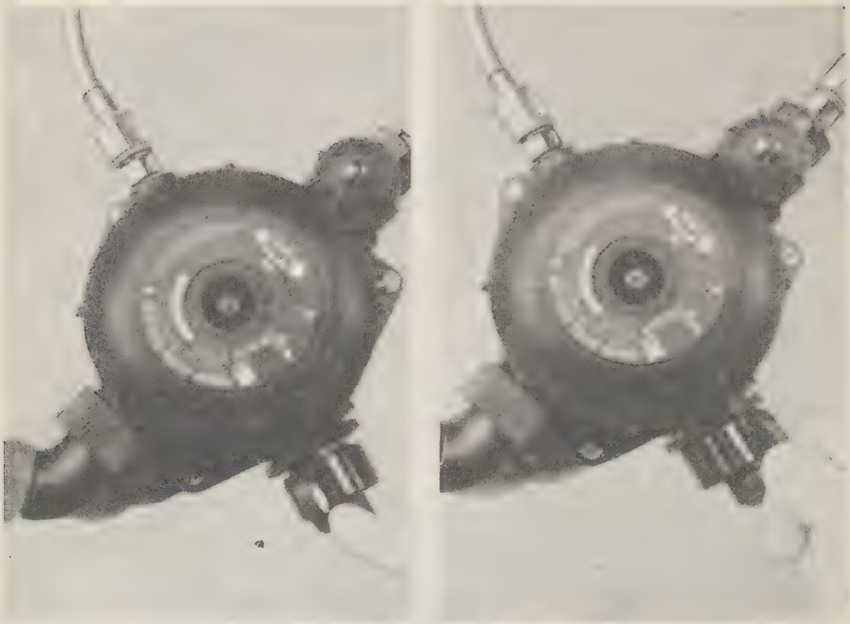

FIGURE 14.—Demand oxygen regulator showing auto-mix and switch to turn it on and off.

(2) Opening the emergency valve converts the demand system into a continuous-flow system. *It is an emergency device for use only if the demand system fails to function.* It is extremely wasteful if used when not needed, for the oxygen supply limits the range of high-altitude missions as certainly as the supply of gasoline.

29. Demand mask.—*a.* Since the demand regulator releases oxygen only in response to the suction of inspiration, the mask which

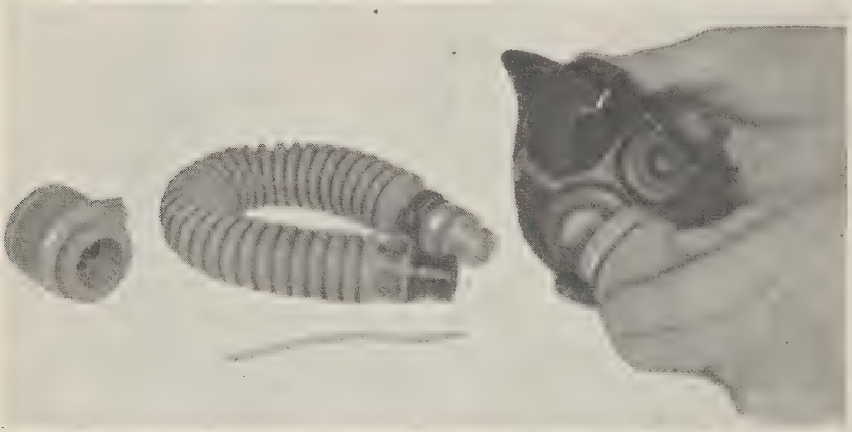

FIGURE 15.—Conversion of type A–8B mask into demand mask.

is used with it must fit tightly to the face to insure an adequate oxygen supply at extreme altitudes. The mask consists of a facepiece with an expiratory valve mounted in it, a connecting tube for oxygen supply, and straps for suspending it from the helmet. There are four types in use at the present time:

(1) The A–9, of which only a few have been made; this type is like the A–10 except that it has no nose strap.

(2) The converted A–8B. (See figs. 15 and 16.)

FIGURE 16.—Demand mask ready for use.

(3) The A–10.

(4) The revised A–10.

The latter two are the standard types.

b. Type A–10 demand mask is designed to fit the face like a glove fits the hand. Consequently it is important to adjust each mask correctly to the user's face.

c. Mask leaks become extremely dangerous above 30,000 feet. A small leak may become larger in high altitude because of decreasing density of the air. To test for mask leakage, hold the thumb over the end of the inspiratory tube and inhale gently. If the mask does not leak, it will tend to collapse on the face. A surer method is the gas analysis made by means of the oxygen officer's test set.

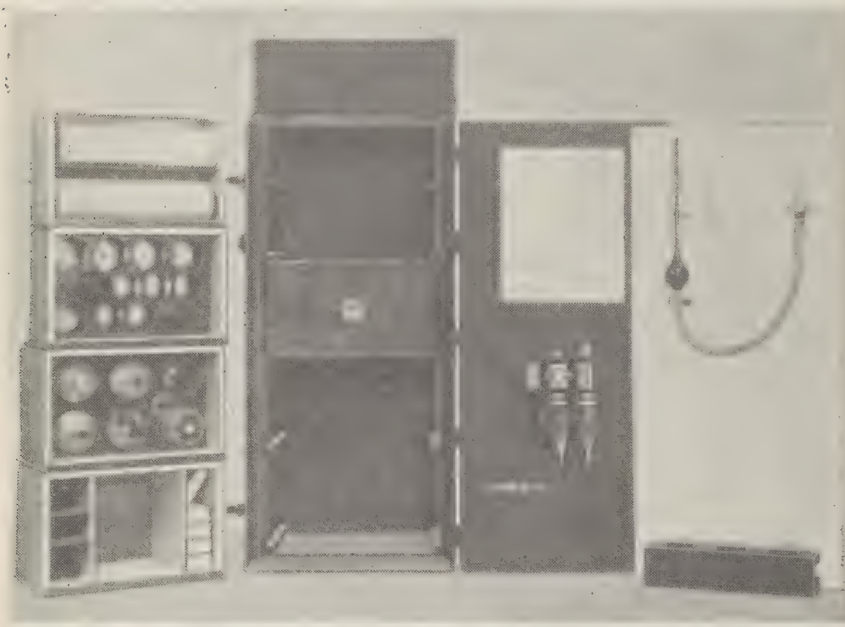

FIGURE 17.—Field unit for testing masks. The Scholander analyzer is mounted on the board to the right. Reagents and spare parts are contained in drawers at left.

30. Nitrogen test set.—*a.* The oxygen officer's test set (see fig. 17) tests for nitrogen in the air within the mask after the wearer has been breathing through the system, with the auto-mix off, for 6 minutes. Since the intake from the regulator is 100 percent oxygen, any nitrogen which appears in the mask must be derived from air that is leaking into the system around the mask.

b. Using the oxygen officer's flat kit, a measured volume of a mixture containing nitrogen, oxygen, carbon dioxide, and water vapor

is taken directly from the mask by means of a hypodermic syringe (see fig. 18). This sample is then injected into the burette. (See fig. 19.) All gases but nitrogen are absorbed. The burette is calibrated to read in percentages of nitrogen. Full directions accompany the equipment.

FIGURE 18.—Withdrawal of sample of gas from the microphone turret of type A–10 mask, by means of a 5-cc syringe used with Scholander apparatus.

(1) Less than 3 percent nitrogen indicates a satisfactory fit.

(2) Between 6 and 10 percent is objectionably high.

(3) More than 6 percent indicates an unacceptable fit.

31. Precautions in use of demand system.—*a. Before the flight.*—(1) Check pressure of oxygen tank; it should not be less than 400 pounds per square inch.

(2) Check emergency flow to show that lines are clear; then shut off the emergency knob tightly.

(3) Make sure that knurled collar at outlet end of regulator is tight.

(4) Be sure that the male end of the rapid disconnect has its rubber gasket in place.

(5) Be sure the male end of the rapid disconnect fits snugly into the orifice of the hose from the regulator at your station. A pull of 10 pounds or more should be required to separate the two.

(6) Have mask adjusted for particular helmet or headstrap to be used.

FIGURE 19.—Injection into Scholander analyzer of sample of gas obtained from mask (fig. 18).

(7) Clip the oxygen supply hose by means of spring clip onto the clothing or parachute harness, close enough to the face so that the tube of the mask will permit free movement of the head without kinking or pulling.

(8) Be sure the auto-mix is in the "on" position.

b. In the air.—(1) Manipulate mask to free it of ice at regular intervals when temperature is low enough to cause ice formation in the mask.

(2) When the mask is first put on, or when it is replaced after temporary removal, always check for leaks by blockage and gentle inhalation.

(3) Should signs of impending anoxia appear, open the emergency valve, but only in absolute necessity. Check oxygen equipment to discover the cause of the anoxia.

(4) Check oxygen pressure gages frequently.

c. On return to the field.—(1) Wipe mask dry; or wash with soap and water, rinse thoroughly, and dry.

(2) Never lend your mask; it may not fit the borrower and leaves you without one.

(3) Inspect the facepiece of mask for cracks and leaks.

(4) Change strap adjustment only to take up on natural stretch slack.

d. Be sure that—

(1) All lines, fittings, instruments and other items are free from oil, grease, and other foreign matter.

(2) No lubricants are used in the oxygen system.

32. Portable cylinder and regulator assembly.—*a.* The walk-around bottle (see par. 24*c*) holds from 4 to 8 minutes' oxygen supply, depending upon the altitude and activity of the user (see fig. 20). In an airplane fitted with demand system equipment, the regulator on the walk-around bottle contains a filler adapter, through which the cylinder can be recharged directly from the airplane's oxygen supply by means of portable filling hoses.

b. The regulator on the portable cylinder also contains a pressure gage, a gripping clamp, and a special covered outlet.

(1) The pressure gage shows how much oxygen is in the cylinder. The cylinder should be kept charged at all times ready for emergency use.

(2) The gripping clamp permits the portable assembly to be fastened readily to parachute harness or clothing for ease in movement.

(3) The special outlet contains a fitting which permits the mask to be plugged directly into the regulator.

c. Aside from its obvious use in large airplanes at high altitudes, when personnel must move about performing duties, and in parachute descents, the walk-around bottle has another very important application. In case a crew member has to go to the assistance of a fellow crew member, he takes along his walk-around bottle, plugs it into the

portable refilling hose at the new station, and leaves it plugged in. This connects him directly to the supply line and, in effect, provides two outlets at every station. If greater mobility is needed, he can

FIGURE 20.—Walk-around bottle for use in demand oxygen systems. This cylinder is always painted green.

connect the wounded crew member to the portable refilling hose and he himself can use the regular outlet at the station. As the airplane pressure goes down, walk-around bottles are filled less and less completely. (See fig. 21.)

FIGURE 21.—Interior of a mobile decompression chamber. By means of chambers of this type individual tolerance to high altitude is tested.

SECTION VII

CARBON MONOXIDE POISONING

33. Physical causes.—*a*. Carbon monoxide, an odorless and colorless gas, normally occurs in the exhaust fumes of aircraft engines as a result of incomplete combustion of carbonaceous material. The percentage varies from 1 to 7 percent, with an average of 2.8 percent.

b. There is little or no danger from exhaust fumes in twin-motored or four-motored aircraft. The gas occurs principally when the engine is placed immediately in front of the personnel compartment. Then the amount of exhaust gas entering the compartment depends largely on the manifold system.

c. The worst condition is usually encountered in engines with short exhaust stacks. Experience has shown that the exhaust gases should be discharged at a distance from the slipstream which immediately

surrounds the fuselage. Care should be taken that all openings in the fuselage and fire wall are closed.

d. Leaks in cabin heaters which utilize the exhaust gases are other potential sources of danger.

e. During combat, enemy gunfire may open up exhaust collector rings and holes in the fuselage and fire wall, causing dangerous concentrations of carbon monoxide in the cabin.

34. Physiology.—Carbon monoxide is more dangerous at higher altitudes than at ground level because a small loss in the oxygen-carrying power of the blood will produce anoxia. (See fig. 22.) It knocks out the transportation system of the blood-carrying oxygen. This is due to the fact that carbon monoxide combines with the hemo-

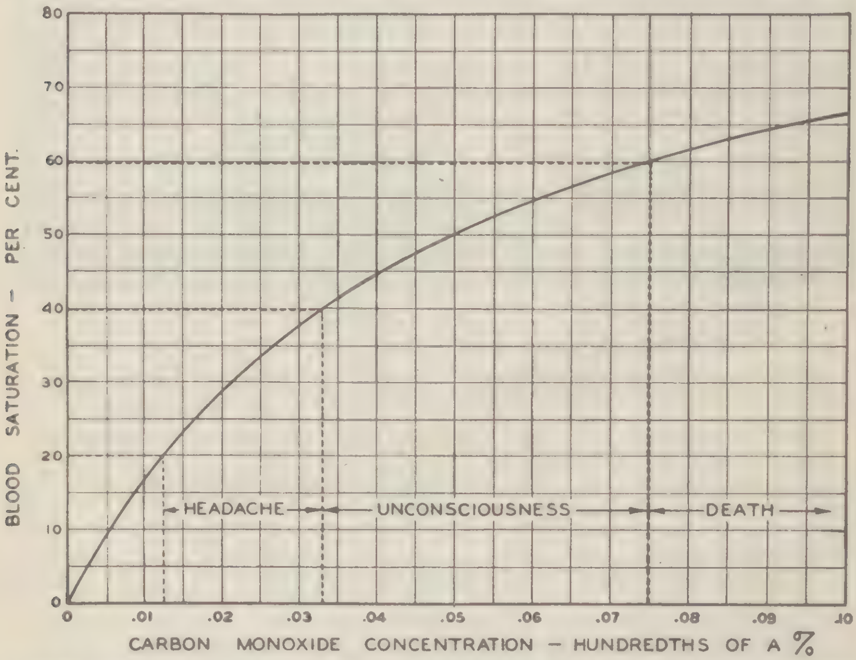

FIGURE 22. Saturation of the blood with carbon monoxide and resulting symptoms produced by various concentrations of carbon monoxide in inspired air.

globin of the blood in a manner similar to that of oxygen; but hemoglobin has about 200 times the affinity for carbon monoxide that it has for oxygen, hence hemoglobin combines with carbon monoxide more readily than oxygen, and gives it up less readily than oxygen. The carbon monoxide hemoglobin thus formed decreases the amount of hemoglobin available to transport oxygen to the tissues.

35. Symptoms.—The symptoms of poisoning vary with the carbon monoxide content of the blood as shown in Table II and Table III.

They are governed by three factors which usually work in combination, causing severe symptoms:

a. Concentration of carbon monoxide.

b. Duration of exposure.

c. Altitude.

36. Prevention.—*a.* In single-engine airplanes, it is often difficult to prevent any fumes from entering. The maximal permissible concentration in personnel compartments of the Army Air Forces aircraft has been established as being 0.005 percent (one part per 20,000).

b. Dangerous concentrations of carbon monoxide in aircraft compartments are indicated by—

(1) Subjective symptoms, such as throbbing headache, nausea, dizziness, or dimming of vision.

(2) Odor of exhaust gases.

TABLE II.—*Symptoms which develop at various concentrations of carbon monoxide in the blood*

Percent of carbon monoxide in blood	Symptoms
0–10	None.
10–20	Tightness across forehead, possibly slight headache, dilatation of cutaneous blood vessels.
20–30	Headache, throbbing in temples.
30–40	Severe headache, weakness, dizziness, dimness of vision, nausea and vomiting, collapse.
40–50	Same as previous symptoms, with increased pulse rate and respiration and more possibility of collapse.
50–60	Fainting, increased respiration, Cheyne-Stokes respiration, increased pulse, unconsciousness with intermittent convulsions.
60–70	Unconsciousness, with intermittent convulsions, depressed heart action—possibly death.
70–80	Weak pulse and slow respiration, respiratory failure and death.

TABLE III.—*Dangerous concentrations of carbon monoxide*

Concentration (percent)	Effect
0.01, or 1 part in 10,000	No symptoms for 2 hours
0.04, or 4 parts in 10,000	No symptoms for 1 hour
0.06 to 0.07, or 6 to 7 parts in 10,000	Headache and unpleasant symptoms in 1 hour
0.10 to 0.12, or 10 to 12 parts in 10,000	Dangerous for 1 hour
0.35, or 35 parts in 10,000	Fatal in less than 1 hour

c. The following action must be taken at any indication of carbon monoxide:

(1) Open all cockpit hoods or windows to eliminate any odor of exhaust fumes by ventilation.

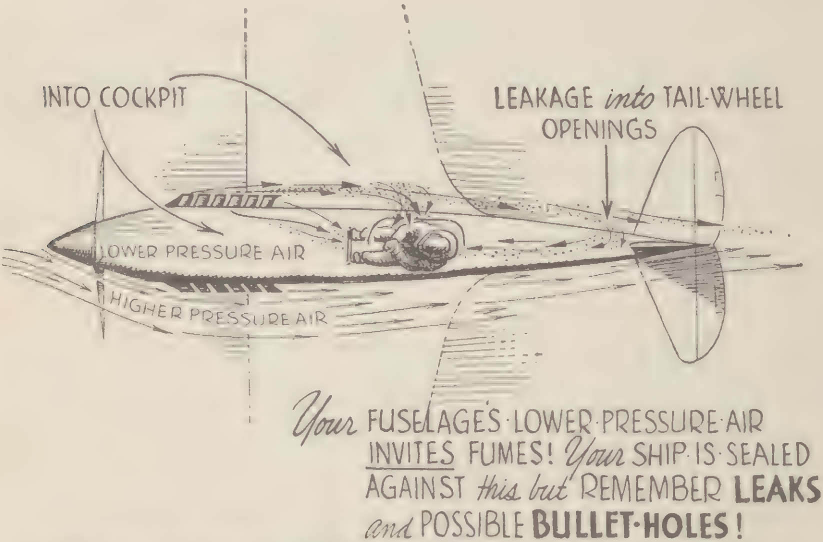

FIGURE 23.—How carbon monoxide gets into the cabin of an airplane—schematic.

(2) Attach oxygen masks and breathe pure oxygen until the symptoms disappear.

(3) Descend to lower altitudes as soon as possible.

(4) Turn off exhaust type heaters if they are being used.

SECTION VIII

EFFECTS OF RAPID CHANGES OF MOTION AND DIRECTION UPON THE HUMAN BODY

37. Forces and effects of acceleration.—*a.* Acceleration means a change in velocity in either magnitude or direction, or both.

b. Every body continues in its state of rest or uniform motion in a straight line unless impelled by external force to change that state.

c. The force that is required to produce a given acceleration to an object is dependent directly on its mass. This is expressed by the formula:

$$\text{force} = \text{mass} \times \text{acceleration}$$

$$\text{acceleration} = \frac{\text{force}}{\text{mass}}$$

d. The earth exerts an attraction on all bodies toward its center. This attraction is called gravity. When an object falls through space without resistance, as in a vacuum, there is an increase in velocity or in acceleration which is referred to as the acceleration due to gravity. The weight of the body at rest (the weight of the body felt by the individual while sitting in a chair) is always the force of gravity and is represented by the symbol g.

e. A force directed in one direction by the airplane produces an equal but opposite force in each of the flying personnel. In other words, when the airplane acts on the body with the force in the direction *seat to head*, the inertia of the human body acts in the direction *head to seat*. However, to simplify this matter, forces will always be considered as applied in the direction in which the body reacts.

38. Types of acceleration.—*a.* Linear accelerations involve change of speed in a straight course. Examples are take-offs, landings, catapult take-offs, crash landings, and parachute opening impacts.

b. Angular accelerations are caused by change in rate of rotation, such as produced by spins, tight banks, etc. Since they affect the body chiefly by producing dizziness, they will not be discussed at any length.

c. Centripetal or radial accelerations, directed toward the center of rotation, depend on the rate of change of direction and speed in a curved flight, as in turns, interruption of dives, and loops. (See fig. 24.) This acceleration sets up a force of inertia called "centrifugal force," acting in the opposite direction. A simple example of centrifugal force is the swinging of a pail filled with water over the head without spilling a drop. The amount of centrifugal force in these maneuvers is directly proportional to the square of the linear flight velocity and is inversely proportional to the radius of its curved path. In other words, the sharper the turn (shorter the radius), the greater the force. (See fig. 25.)

39. Measurement of acceleration.—*a.* As stated in paragraph 37 *d*, the weight of a particular body is represented by the symbol g. It is constant at all times for that body. The force exerted on a body under ordinary conditions is referred to as 1 g.

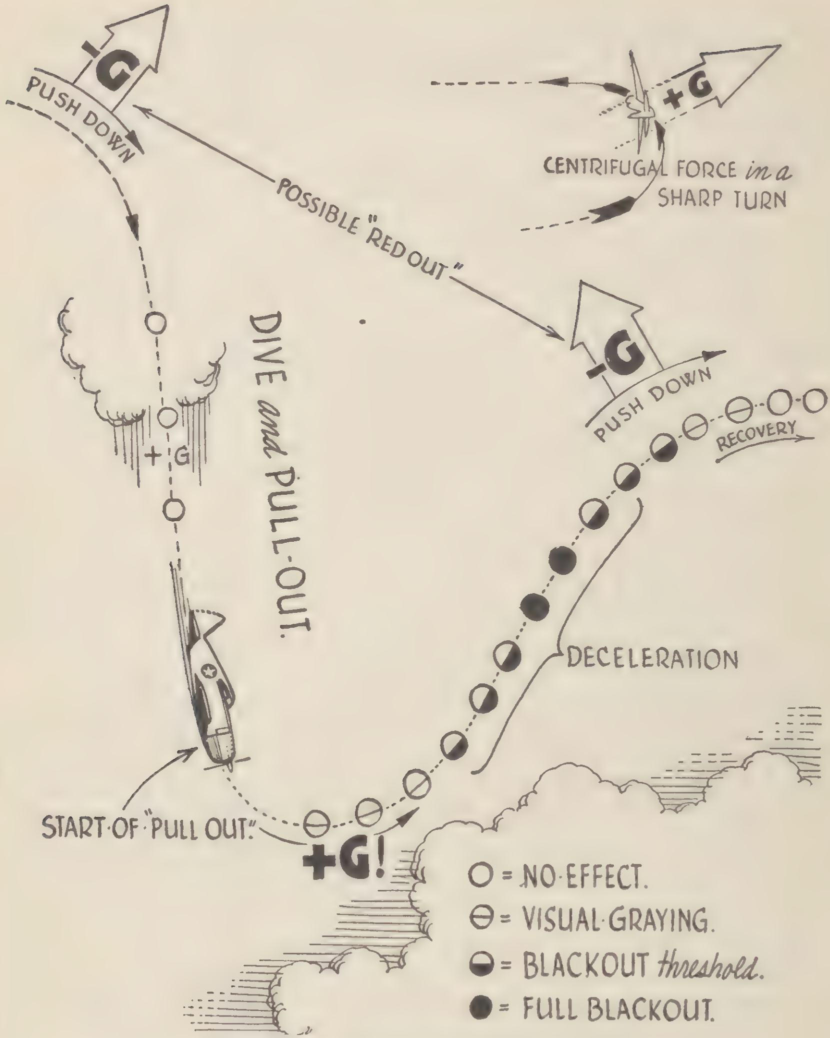

FIGURE 24.—Effects of acceleration (+G).

b. Positive acceleration refers to the force acting from head to seat, as in an inside loop. It is expressed as $+g$.

c. Negative acceleration refers to the force acting from seat to head, as in an outside loop. This is expressed as $-g$.

40. Effects of positive acceleration.—*a*. At $+2\ g$, the subject is pressed firmly into the cockpit seat; at $+3$ to $+4\ g$, movement of the arms and legs becomes difficult or impossible and the soft tissues of the face and body are drawn downward; at $+4$ to $+5\ g$, acting from 3 to 5 seconds, visual disturbances begin to make their appearance. These

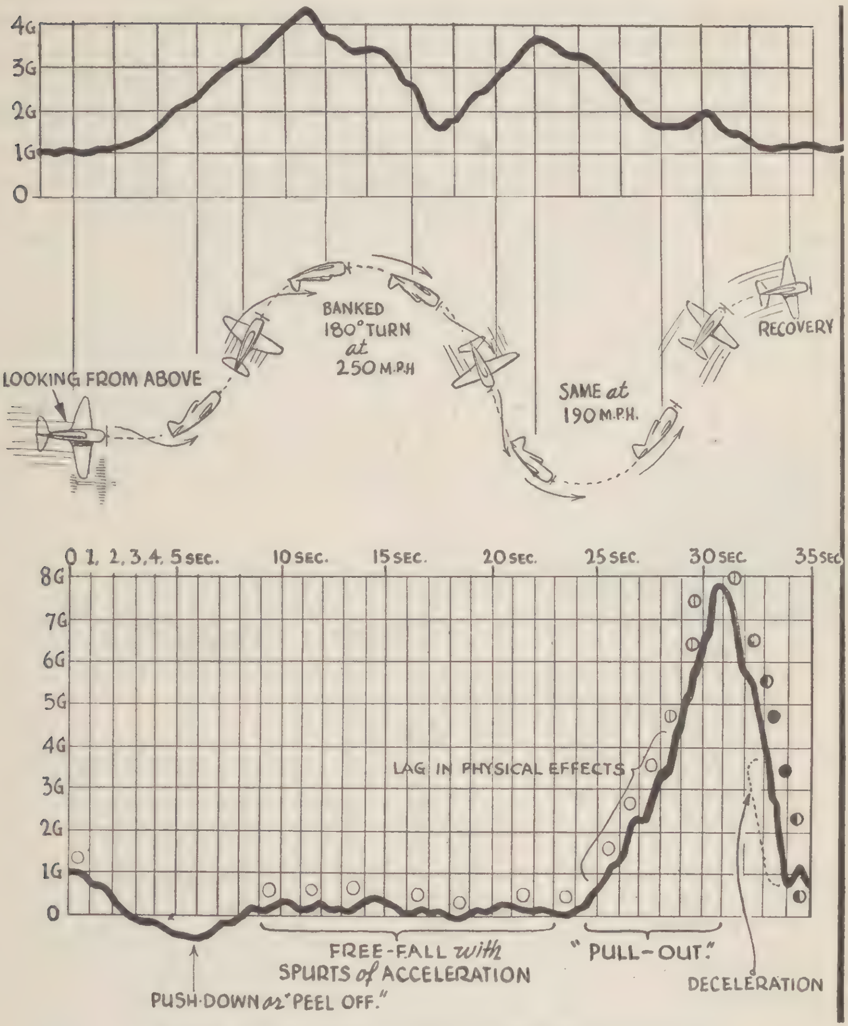

FIGURE 25.—Possible G-graphs on pursuit ship maneuvers.

visual symptoms are first blurring or "graying" of vision, then blacking out (complete loss of vision). There is also a dullness of hearing and an increased reaction time. At +3.5 to +4.5 *g*, acting for 3 to 5 seconds, consciousness is lost by the average individual. (See fig. 26.)

b. Symptoms disappear almost immediately on cessation of the centrifugal force except in cases of unconsciousness. Then there is a period of 5 to 10 seconds of confusion and disorientation before full recovery.

41. Physiological reason for unconsciousness and "blacking out."—*a*. The disturbances resulting from positive acceleration are

due to decreased blood supply to the brain. Returning to the earlier analogy of swinging a pail of water, the same thing results in positive acceleration. However, in this instance, instead of the water flattening out and clinging to the bottom of the pail, it is the blood in the human body which is forced downward, away from the head and eyes and toward the feet. This occurs because the large blood vessels of

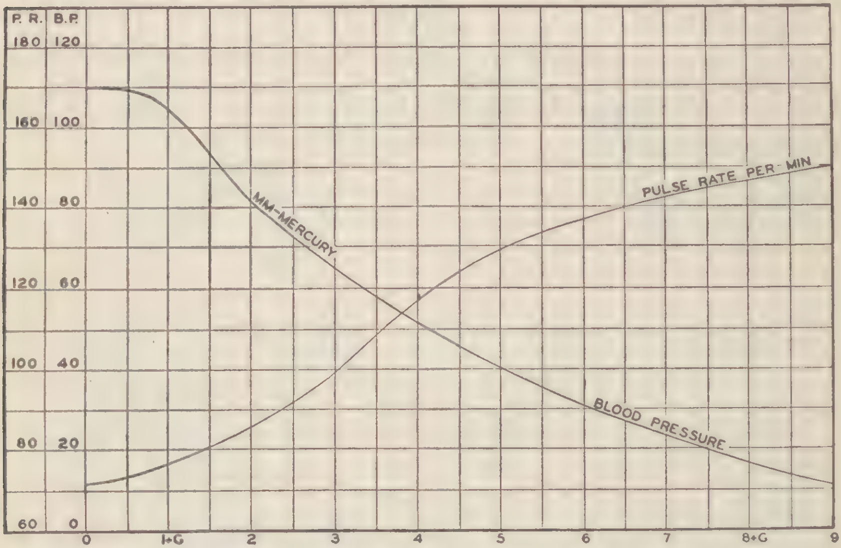

FIGURE 26.—Effects of acceleration (+G) and centrifugal forces upon blood pressure and blood rate.

the body lie in a head-to-seat direction and are elastic tubes. It has been shown that in the vicinity of $+7\ g$, as much as a pint of blood may be displaced into each leg. With the blood thus distributed there is an inadequate return of blood to the heart. which in turn reduces blood pressure.

b. Another factor involved is that the column of blood between the heart and the brain is about 12 inches in height. At $+5\ g$, the centrifugal force increases the weight of the blood five times. Thus, for blood to reach the brain it is as if the heart were to push a column of blood upward for the equivalent of 60 inches. (See fig. 27.)

c. Graying or blacking out occurs at a lower value and shorter duration of $+g$ than does unconsciousness. The reason for this is that the normal eyeball has an internal pressure of about ½ inch of mercury and the arteries supplying blood to the retina of the eye must overcome this pressure before blood can enter this area. There is no such counterpressure in the brain itself. For that reason, during

positive acceleration, the decrease in blood pressure, although not affecting the brain, immediately affects the circulation to the retina of the eye. It has also been proved that the retina is more sensitive to lack of oxygen than is the brain tissue.

42. Effects of accelerations acting transversely to long axis of the body.—Centrifugal forces acting transversely to the long axis of the body do not cause disturbances as easily. The tolerance of human beings to centrifugal forces is increased when they assume the prone position. It has been demonstrated that they can withstand $+12$ to $+14\ g$ acting transversely for 120 to 180 seconds. Visual disturbances may occur above $+14\ g$. This is due to the fact that in the prone or supine position, the centrifugal force acts at right

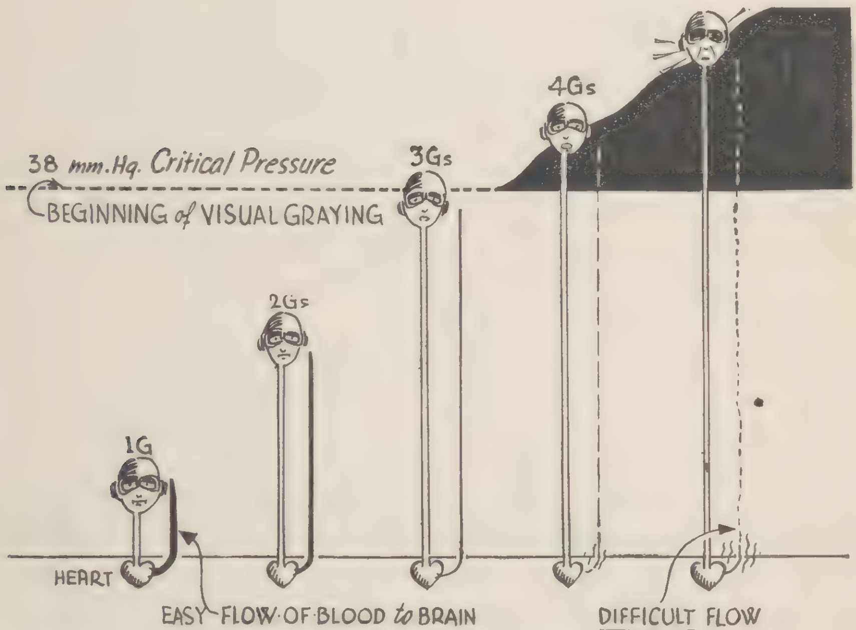

FIGURE 27.—Diagram of amount of force the heart exerts at different degrees of acceleration (G).

angles to the great blood vessels, causing no displacement of large masses of blood.

43. Effects of negative accelerations.—*a.* In this type of acceleration, such as in the outside loop, the limit is reached at the much lower values of -2 to $-3\ g$.

b. The symptoms are a "gritty" sensation in the eyelids; the eyeballs feel as if they would pop from their sockets. There is a throb-

bing pain in the head. for now the reverse process of positive g is occurring. Instead of the blood draining to the feet, it is being pushed into the head, causing ocular and cerebral congestion. At $-3\ g$ the visual field assumes a reddish hue known as "red out."

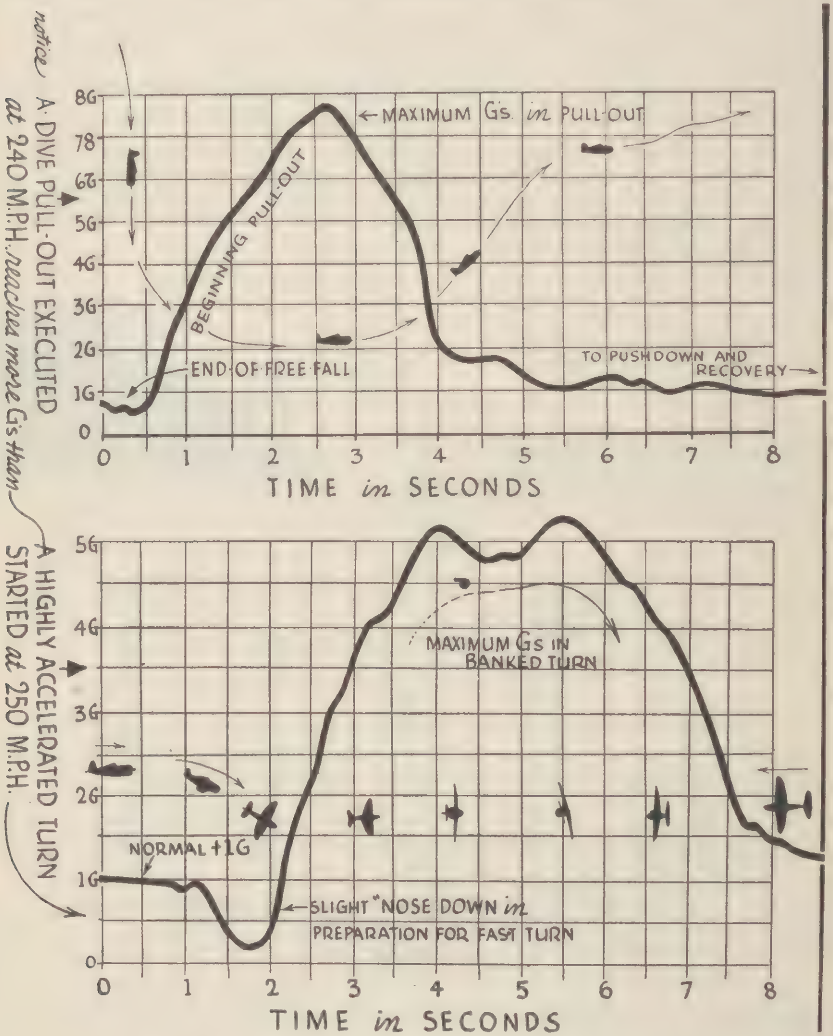

FIGURE 28.—Typical g-reactions in pursuit ship maneuvers.

c. Serious complications such as retinal and cerebral hemorrhages will occur if more than $-3\ g$ is encountered. Even below $-3\ g$ symptoms may persist for several minutes to several hours. It is best to avoid maneuvers which induce high negative accelerations,

such as outside loops. Neither the airplanes nor the men who fly in them are able to withstand such strain.

44. Methods of preventing "blacking out."—*a.* Although there is a much greater tolerance when forces are acting transversely to the long axis of the body, it is relatively difficult to operate the airplane from a prone or supine position.

b. The crouch position has been used by both the Germans and the British. The rudder bars are elevated or the cockpit seat lowered. The feet are raised as high as possible. Thus, when a flyer pulls out of a dive, the trunk of the body is bent forward on the thighs; the head is drawn back so that he can still see ahead to some degree. The heels should be at a level with the buttocks. Between +1 to +2 *g* additional "*g*" tolerance can be obtained by this method. The crouch position is effective because—

(1) It shortens the vertical distance the blood has to be pumped from the heart to the brain.

(2) By placing the body in a somewhat transverse position in relation to centrifugal force, the reservoirs, or cavities, in which the blood might be pooled are reduced.

c. Factors which tend to decrease resistance to high centrifugal force are fatigue, excessive smoking, excessive drinking, loss of sleep, anoxia, colds, diarrhea, and recent illness.

SECTION IX

EQUILIBRIUM AND AIRSICKNESS

45. Mechanism of equilibrium.—*a.* Equilibrium or balance is maintained by means of muscle sense, the eyes, and the semicircular canals of the inner ear.

b. Muscle sense is derived from sense organs located in the muscles and joints. These organs enable a person to control movements of muscles and to know in what position the body and limbs are located.

c. The organ of sight is another essential organ of equilibrium. Muscles of the eyeball are controlled so that although the body turns, objects may be perceived as if they were standing still, and space orientation is maintained.

d. The semicircular canals are minute passageways within the inner ear on each side. Every change in the position of the head causes a movement of the fluid contained in these canals. In turn,

this movement sets up a vibration of sensory hairs lining the canals. This vibration causes impulses to travel along the nerves of the ear to the brain, and we interpret these as change in position. There are three semicircular canals in each ear. The three are placed at right angles to each other to cover three planes of movement. (See fig. 29.)

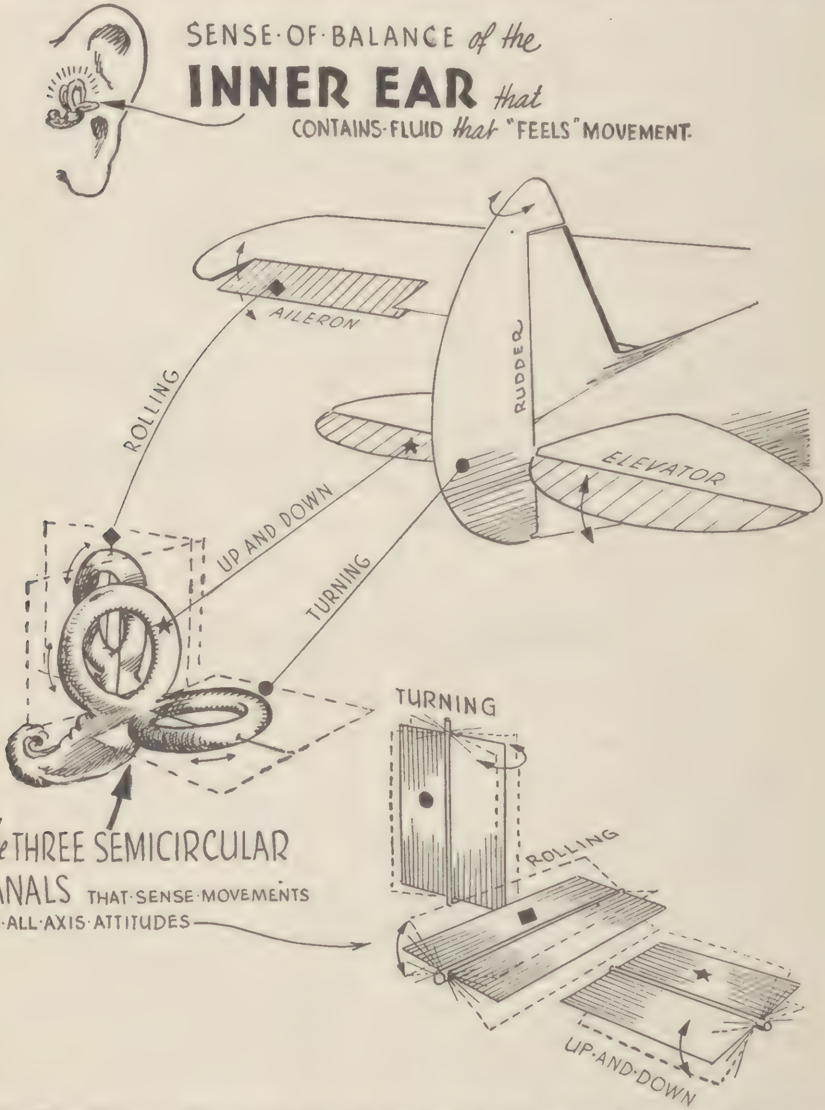

FIGURE 29.—Diagram of inner ear, showing how semicircular canals act as sense of balance.

46. Blind flying.—*a.* Proper function of at least two of the elements mentioned in paragraph 45 are essential if balance is to be maintained. In flight a pilot depends on the horizon as a reference

line by which he can adjust the position of his airplane. This visual reference is lost at night or when passing through clouds or weather. Sensory impressions emanating from the vestibular apparatus, the muscles, joints, viscera, and skin are prevented in flight because of the effects of centrifugal force, centripetal force, acceleration, deceleration, and unpatterned motions of the aircraft. Hence, all the burden is carried by the inner ear, and that is not enough, for acting by itself, it gives the wrong information to the flyer.

b. The inner ear acting alone as the human equilibrium mechanism will prove false in the following ways: It will give a feeling of—

(1) Ascent while turning.

(2) Sinking on recovery from a turn.

(3) Tilt to the opposite side during a turn.

(4) Tilting when flying between two cloud banks of different slope, especially when they are sloping toward each other.

(5) Turning during a level flight.

(6) Due to movements of the head, the airplane tipping during too sharp a turn.

(7) Spinning to the left after a spin to the right, and vice versa.

c. For the reasons in *b* above, during blind flying, such sensations must be disregarded and the flyer must depend completely on the certainty of his instruments which correspond to the three planes of equilibrium: the turn and bank indicator, air speed, altimeter, and rate of climb or descent indicator.

47. Cause of airsickness.—*a*. Airsickness is a form of motion sickness, and is similar to carsickness and seasickness. It may be due to various movements of the airplane in flight, as follows:

(1) Random movements, such as pitching, bumping, yawing, and corkscrew motions.

(2) Bumping, due to "prop-wash", caused by flying in the rear of a large formation.

(3) Purposeful movements, as caused by the pilot in acrobatics.

b. The flyer has three means of perceiving change in position: the eyes; the organs of balance in the inner ear; and the muscles and joints. Sensations from these sources are transmitted to the brain.

c. The apparatus of the ear is not able to distinguish between gravity which it normally encounters, and accelerations which occur in flight. The eyes, on the other hand, are controlled in part by what is seen, and in part by nerve impulses from the internal ear. For that reason, sensations coming from the internal ear are in contradiction to those sent out by other sense organs. These confusing and contradictory nerve impulses received by the brain are the chief basis for airsickness.

d. Other contributing factors to airsickness are noxious odors (such as that of gasoline), cold, noise, vibration, lack of visual orientation, and psychological factors such as fear of flight.

48. Symptoms and treatment of airsickness.—*a.* The symptoms of airsickness are yawning, belching, pallor, salivation, abdominal discomfort, sweating, nausea, vomiting, headache, weakness.

b. Treatment of airsickness is very limited. Drugs are not satisfactory. There are certain preventive measures:

(1) If tactfully possible, fly in a smooth stratum of air.

(2) Wear warm and comfortable clothing.

(3) Cushion the body against vibrations of the airplane.

(4) Use cotton earplugs to reduce noise.

(5) Drink few liquids and eat no greasy foods.

(6) If possible, get a good visual reference in order to avoid special disorientation.

(7) Sit as close to the center of gravity in the airplane as possible.

(8) Good ventilation of airplane.

Section X

NIGHT VISION

49. Physiological structure of the eye.—*a.* An individual who has good vision during the day is not necessarily able to see well at night. This is due to the different structure and mechanisms within the eye for seeing in relatively bright lights and in the dark. The two main factors in the eyes accounting for this difference are the *cones*, which are responsible for day vision, and the *rods*, which account for night vision.

b. The cones are used for the recognition of detail and are located in the central portion of the retina. They are stimulated only by fairly intense illumination. The image of an object looked at directly is formed on these sense organs. Colors and fine details are seen with the cones.

c. The rods are the most sensitive part of the eyes for seeing at night. They cover all the retina except the center to about 40° from the center of the retina. This central portion of the retina is referred to as a "night-blind spot."

(1) Night vision is accomplished by the periphery of the field of vision. For this reason objects in dim light are best seen by looking to one side of, rather than directly at them.

(2) True perception of color is not possible with night (peripheral) vision. One distinguishes between a light and a dark color

at night which in reality is recognition of two different shades of gray.

(3) Perception of fine detail with night vision is impossible. Only the rough outline of an object is perceived.

50. Physiological factors affecting night vision.—*a.* Everyone has had the experience of entering a darkened area like a theater, after having been in a lighted place, with the ensuing difficulty in seeing. It takes from 10 to 30 minutes or more, depending upon how dark the room is, before full night vision functions. This is due to the fact that it takes the rods about 30 minutes to acquire their complete sensitivity. This sensitivity is a 10,000-fold increase over sensitivity in light. Although it requires about 30 minutes to obtain this maximal sensitivity, it can be lost entirely by a very short exposure to bright light. Then the whole 30-minute process of dark adaptation must be repeated to regain maximal sensitivity, although the less bright the light, the sooner the rods will attain maximal sensitivity.

b. The time required for the rods to obtain maximal sensitivity is in proportion to the brightness of the light which ends that sensitivity. For this reason, in an airplane all unnecessary lights should be off and all essential lights kept as dim as possible. Reading of dials should be done rapidly, and the instrument panel should not be stared at unnecessarily.

c. It has been found that practically the same benefits afforded by remaining in a dark room before flying can be gained by wearing special red-lensed goggles. The greatest advantage of this procedure is that normal activities can be continued. It is only necessary for the men flying on a night mission to wear the goggles for 30 minutes before removing them at the time of take-off, if they then continue in a darkened atmosphere. Red-lensed goggles can be used temporarily when the airplane is caught in the glare of a searchlight.

51. Other factors affecting night vision.—*a.* The higher the altitude, the greater the decrease in night vision. At 12,000 feet without supplemental oxygen, night vision is only about half as good as it is at sea level. This is due to lack of oxygen and can be corrected completely by the use of supplemental oxygen. For this reason the use of supplemental oxygen from the ground up is advisable on all night flights.

b. Vitamin A is a chemical factor essential for good night vision. This vitamin is adequately supplied in Army rations.

(1) Foods high in vitamin A, or carotene, are eggs, butter, cheese, liver, apricots, peaches, carrots, squash, peas, spinach, all types of greens, and cod-liver oil.

(2) An excess of vitamin A to an individual already getting enough of it will not improve night vision.

c. There is a very great variation among individuals as regards night vision. For this reason it is advisable that all personnel be checked for night vision and those with the greatest adaptability be assigned to night missions. Night vision can be improved in almost all individuals by practice in glancing off-center while looking at objects in a very dim light. With practice, some men can double their night visual efficiency.

d. Windscreens decrease the amount of light coming to the eye from an object because of the light absorbed and reflected by the windscreen itself. Therefore, the windscreen should be kept scrupulously clean and free of scratches to prevent the scattering of light, and the lights inside the airplane must be kept dimmed or shaded as far as possible to prevent reflection.

Section XI

EFFECTS OF EXTREME TEMPERATURE ON THE BODY

52. Range of temperatures.—*a.* The war is being fought all over the world in every conceivable temperature. It is for this reason that attention is called not only to the extreme cold encountered at higher altitudes, but also to the extreme heat found at ground levels in some locales.

(1) In the desert on the ground, the cabin temperature of an airplane can rise to 120° F. 20 minutes after returning from a flight.

(2) In the Tropics, because of the high moisture content of the air, the radiation intensity from the sun is not as great as in the desert. The temperature is more constant and lies in the range of 80° F. to 90° F. However, the humidity often ranges up to 95 percent, causing extreme discomfort.

(3) In cold climates, the temperature goes as low as from −40° F. to −50° F. Under these conditions, operation and preparation of airplanes for flight are extremely difficult for the air crews, who have to use their hands to perform delicate operations.

(4) In high altitudes, outside air temperatures as low as −110° F. are encountered at 40,000 feet.

b. Since the temperature ranges from +120° to −50° F., it is ob-

vious that no given set of flying clothing can be universally effective. Each locale and situation calls for different measures in dress and heating arrangements. However, one factor is universal and that is the human body and its mechanism.

53. Methods of gaining body heat.—*a.* The most important way in which heat is produced in the body is through combustion or oxidation of food. This is called chemical regulation of body temperature.

b. The slight exertion required to maintain the body in a sitting position increases the production of heat 10 to 20 percent above the basal rate. Walking may raise the production of heat to three times the basal rate, and hard exercise may increase it from ten to fifteen times the basal level.

c. Shivering is a form of exercise consisting of involuntary contraction and relaxation of certain groups of muscles in the body. It may increase metabolism to four or five times the basal rate. This is one of the most effective mechanisms which the body possesses for increasing the production of heat and maintaining a constant body temperature under cold environmental conditions.

d. Food increases the production of heat within an hour after eating. It reaches a maximal increase of 10 to 30 percent above the basal value about the third hour, and maintains this level for several hours.

(1) This is due to excess energy needed to digest and assimilate the food for use in the body.

(2) It is greatest when protein foods are eaten.

e. When sleeping, the production of heat is decreased 10 to 15 percent below the basal level. This is why freezing and death will occur when people fall asleep in the snow and cold.

f. Other minor ways of gaining heat are through—

(1) Taking of food or drink which is hotter than body temperature.

(2) Radiation from hot objects outside the body. On a hot day the body may gain as much as two or three times the basal rate of production of heat.

54. Loss of heat in body temperature.—*a.* Loss of heat from the body is dependent almost entirely on physical factors and is referred to as the "physical regulation of body temperature." It consists mainly of radiation, convection, conduction, and evaporation.

(1) *Radiation.*—In hot weather, or when surrounding objects are above body temperature, the body gains rather than loses heat by radiation. Loss of heat by radiation can be diminished by the use of clothing.

(2) *Convection.*—Loss of heat by convection is dependent on the difference in temperature between the surface of the body and the surrounding air, as well as on the rate of movement of the air over the surface of the body. This loss can also be decreased by the use of clothing.

(3) *Conduction.*—Loss of heat by conduction plays a small part in the regulation of body temperature.

(4) *Evaporation.*—Loss of heat by evaporation is caused by two principal body functions: respiration and perspiration.

(*a*) The air breathed into the respiratory tract usually has to be moistened and heated. For every gram of water thus evaporated in the moistening and exhaling of air, the body loses about 575 calories of heat. The heat loss due to warming air is dependent on the temperature of the air when it is inhaled. It ranges from a 2 to 3 percent total loss of heat at 70° F. (21.1° C.) to 10 to 15 percent if the air is at −40° F. (−72° C.).

(*b*) There are two types of perspiration: *insensible perspiration*, which is continually going on and which remains fairly constant under a wide variety of environmental and physiological conditions; and *sensible perspiration*, or *sweating*, which on a cold day may represent no loss at all, but which on a hot day may account for 95 to 98 percent of the heat loss.

b. Other losses of heat may be due to the taking of cold food or drink, which forces the gut to warm the food or drink to body temperature.

55. Regulation of body temperature.—*a*. Constant body temperature of approximately 98.6° F. (37° C.) is maintained under a wide variety of environmental conditions. The body does this by balancing production and loss of heat in such a manner that the temperature of the internal part of the body remains closely fixed at 98.6° F.

b. Regulation of body temperature is controlled by the heat regulation center located in the brain. This center is very sensitive to variations in body temperature and adjusts the various methods mentioned for the gain and loss of heat.

56. Critical temperature.—*a*. The regulation of heat over a wide range of temperature can be divided into two major zones: upper and lower. The dividing line between these two zones is the *critical temperature* at which regulation by sensible perspiration begins.

(1) The upper zone uses evaporation (sensible perspiration) as the temperature-regulating mechanism of the body.

(2) The lower zone uses the large thermal capacity of the body as well as the shivering reflex as its major protective methods.

b. The critical temperature for the nude body is between 86° to 88° F. This critical temperature naturally is lowered according to the amount and thinness of clothing worn. It is extremely important for the airman to know roughly the critical temperatures at which sweating begins. It is obvious that in flying from a warm environment to a cold environment, the presence of heavy perspiration in clothing is extremely dangerous, because the perspiration will freeze and greatly reduce the insulative qualities of the clothing.

c. Loss of heat by evaporation from the body increases linearly with increasing temperature. This rate of increase in loss of heat with increasing temperature is dependent on the amount of clothing worn.

(1) When an olive-drab shirt and trousers are worn, the critical temperature is 78° F. (25.5° C.). At about 105° F. (40.5° C.) a person would quickly become uncomfortable.

(2) For winter flying clothing, the critical temperature is 60° F. (15.5° C.). At 70° F., the heat would be intolerable after a few minutes. (See figs. 30 and 31.)

FIGURE 30.—Army-Navy standard winter flying suit made of shearling. Helmet is Army-Navy standard type; flying shoes, type A6 AAF; winter flying gloves, standard A11.

FIGURE 31.—Army-Navy winter flying suit open.

57. Clothing.—*a.* Clothing plays a role in extreme heat, just as it does in extreme cold. Properly clothed, a person can tolerate far warmer temperature in the desert sun than he could unclothed, provided that the humidity is low. However, in flying, as has been shown, cold temperatures are the rule.

b. In cold environments, the essential problem is to conserve all heat produced by the body. Under these conditions the secretion of sweat is almost entirely stopped. Loss of heat by evaporation is confined to—

(1) Whatever moisture diffuses through the skin.

(2) Evaporation taking place inside the lungs.

c. Due to the fact that most members of an air crew are in seated positions, no warmth can be generated through exercise; therefore, the burden of retaining and maintaining heat is thrown upon clothing.

(1) Wearing summer flying clothing, personnel will be comfortable for an indefinite period of time at 70° F. (21.1° C.). (See fig. 32.) At 60° F. (15.5° C.) discomfort will soon occur.

FIGURE 32.—Army-Navy summer flying suit. Army-Navy standard flying helmet. Flying gloves, type B2 AAF; mosquito boot for wear in tropics.

(2) When the winter flying suit is worn, comfort can be maintained indefinitely at 30° F. (less than −1° C.). Below that temperature the time limit shortens, depending upon the individual's circulatory system in the hands and feet.

d. In extreme cold it is either the hands or feet which suffer first. Individuals who tolerate cold have excellent circulation in hands and feet. The best policy is to avoid tight-fitting gloves and shoes.

(1) When gloves are used, fingers and thumb should be kept in contact except when it is necessary to make a delicate manipulation. Silk inner gloves, worn inside a mitten outer glove, are better than one pair of gloves, even though they may be heavier than the combined weight of the two pairs of gloves.

(2) The heavy winter flying boot is the best foot protection against cold. This can be augmented by wearing two or three pairs of wool socks and an inner sole, preferably of cork, instead of ordinary oxford shoes.

e. Obviously, the solution to most of these problems is the proper heating of the airplane cabin. At altitudes of less than 30,000 feet, heating systems in pursuit airplanes are reasonably reliable. But in bombing airplanes, extreme cold will always be encountered in exposed turrets and uninsulated waists of bombers. Heat will also be ineffective when the side ports or bomb bays are opened to fire guns, to make photographic observations, or to drop bombs. The greatest difficulty arises in the turrets, for there the space is so limited that the personnel have to be chosen carefully as to size, and the whole purpose is destroyed if the gunner is so heavily clothed that he cannot get to his station.

f. Electrically heated clothing is the most logical method for heating personnel in such cramped and exposed places, for such an outfit takes up little more room than the summer flying suit. (See fig. 33 ① and ②.) However, an electrically heated suit has certain disadvantages:

(1) In case of power failure, a seated gunner would be protected at a temperature of 0° F. for approximately a half hour.

(2) It would furnish scant protection in case of forced landing over any cold terrain. At present, electrically heated clothing has its best tactical use in flights over zones of moderate or tropical temperatures.

58. Summary and conclusions.—*a.* A flying suit should have the highest possible heat value with the least possible bulk. The electrically heated suit is more nearly ideal, but is of little value if the electric power source fails, as in a forced landing.

b. Several layers of clothing are better than one solid layer of equal thickness. (See fig. 34 ①, ②, ③, ④, and ⑤.)

c. Clothing should fit loosely so as not to constrict circulation, but not so loose that it becomes snagged.

① Two-piece electrically heated suit, with electrically heated gloves and shoes. Used with standard Army-Navy flying helmet. (This suit has been tested for periods of over 8 hours at −65° C. with no discomfort to wearer.)

② Electrically heated flying suit (open).

FIGURE 33.

① Inner layer of the new AAF three-layer winter flying suit, so constructed that the different layers can be used in various combinations depending upon the temperature encountered. The inner layer is adequate for fairly cold flying temperature, but is light enough to be worn without discomfort in moderate weather.

② Second layer of AAF three-layer winter flying suit.

FIGURE 34.

③ Outer layer of pants, AAF winter flying suit.

④ Complete AAF three-layer winter flying suit, worn with muckluks for use on snow-covered ground.

FIGURE 34—Continued.

⑤ Complete AAF three-layer winter flying suit with parka turned up.

FIGURE 34—Continued.

d. Clothes should be dried thoroughly after use and stored in a dry place. Perspiration may freeze into ice in clothing at high altitudes and ice is a good conductor of heat rather than an insulator.

e. Rubber is the best waterproofing material. Rubber boots will keep the feet dry in mud, wet snow, or water. Rubber, however, is a poor insulator against cold. A light pair of rubbers or galoshes over heavy wool socks, felt boots, or flying boots will keep the feet dry and warm.

f. Clothing must be porous enough to allow the escape of perspiration.

g. Clothing must be flexible and must be of a type that can be put on rapidly and conveniently. (See fig. 35.)

h. Clothing must not impair vision.

i. All pockets should have zippers or snap fasteners to make their contents easily accessible and to hold the contents securely when closed.

FIGURE 35.—New type Army-Navy A2 intermediate flying jacket with fur collar.

j. Several pairs of gloves are needed. One combination is a silk or rayon glove worn next to the hand, a wool glove over this, and a leather gauntlet over all. Gloves should be built for the normally clenched-hand position.

k. For working on the ground in mud, wet snow, or water, shoe packs are useful. These consist of rubber up to the ankle with oiled leather tops. Heavy wool socks and felt inner soles should be worn. This combination gives excellent protection against cold and air. In extremely cold weather, a heavy felt sock covered with a low, rubber, buckled overshoe offers excellent protection against cold.

l. Leather is a poor insulator and for that reason leather footgear is generally unsatisfactory. In addition, it is difficult to keep leather in waterproof condition. Dry leather is fairly satisfactory in aviators' clothing, such as jackets and trousers.

m. The use of clothing depends on weather conditions and climate. Each flyer must use his judgment and knowledge as to what combinations of clothes to wear when the choice is left to him. The mission

to be flown is the primary consideration, but he must remember the possibility of emergency landings, with subsistence problems to be met in Arctic, mountainous, tropical, or desert areas. (See fig. 36.)

FIGURE 36.—AAF two-piece battle dress

SECTION XII

TYPES OF FIRST-AID KITS

59. Aeronautic first-aid kits.—*a.* There are two types of first-aid kits immediately available for flyers in flight. The larger kit, known as *kit, first-aid, aeronautic*, is installed in airplanes, and the smaller and more compact model, known as *packet, first-aid, parachute.* is designed to be tied to the flyer's parachute harness so that

it will be quickly available to him in the event of bailing out of the airplane.

b. The location of the larger kit varies with the individual airplane. In pursuit airplanes it is generally within easy reach of the pilot, either behind the seat or in the cockpit. In multiplace planes provision is generally made to furnish approximately one kit for each two men.

FIGURE 37.—Kit, first-aid, aeronautic.

c. The kit, fist-aid, aeronautic (fig. 37), contains the following items:

(1) Three dressings, first-aid, small.
(2) One tourniquet, field.
(3) Two morphine syrettes, ½-gr. solution.
(4) One package, iodine swabs, 10 min.
(5) Bandage, gauze, adhesive, 1 yard by 1 inch.
(6) One package of sulfanilamide crystals, in envelopes.
(7) One box of eight sulfadiazine tablets.

(8) Burn-injury set (boric acid ointment).
(9) One pair of scissors.
(10) One bottle halazone tablets (100 in bottle).
(11) Eye-dressing set.

FIGURE 38.—Packet, first-aid, parachute.

d. The packet, first-aid, parachute, contains:
(1) Dressing, first aid, small.
(2) One tourniquet, field.
(3) One morphine syrette.

60. Treatment and use of first-aid kit.—*a*. The object of the kit is to furnish first-aid treatment as rapidly and efficiently as possible in an emergency. All flyers should understand the principles of administering such treatments, particularly while flying combat missions when every minute counts and every man not immediately available may make the airplane and its members liable to destruction.

b. In all injuries, if it is possible, give the patient oxygen. If using the demand system, turn the auto-mix regulator to "off" thus insuring a 100-percent oxygen supply.

c. In wounds, the primary treatment is to stop the flow of blood:
(1) Cut away the clothing.

(2) Sprinkle sulfanilamide crystals into the wound.

(3) Apply wound dressing.

(4) Swallow two sulfadiazine tablets every 5 minutes until all twelve tablets are used. Swallow the tablets whole without chewing. Drink plenty of water.

d. If the firm application of the wound dressing does not stop the bleeding, or if there is actual spurting of blood, which would indicate that the bleeding comes from an artery, then:

(1) Apply a tourniquet in a place between the wound and the heart. The tourniquet must not be left on for longer than 15 minutes at a time. As soon as the bleeding stops, the tourniquet should be removed. The wound dressing will keep the hemorrhage from renewed bleeding.

(2) If possible, elevate the bleeding part above the level of the heart.

e. Fractures are of two types: simple, when the skin is not broken; compound, when a visible wound accompanies the breaking of the bone. To treat a simple fracture:

(1) Do not move the injured limb until the splint is applied.

(2) Straighten the limb by pulling gently and steadily.

(3) Apply the splint along the full length of the fractured extremity.

(4) Splints can be made of any relatively firm, straight, flat material such as a board, rolled newspapers, a magazine, rifle, etc. There are undoubtedly pieces or parts in each airplane which can be utilized as splints in an emergency. It would be advisable for the flyer to learn before take-off what part of the airplane can be used in such an event.

(5) Bind splint firmly, but not so tight that it cuts off circulation. This will be indicated if the end of the leg or arm becomes pulseless, cold, and numb.

f. A compound fracture is treated as follows:

(1) Sprinkle the wound with sulphanilamide crystals.

(2) Apply wound dressing and bandage.

(3) In the event of severe bleeding apply a tourniquet. Release the tourniquet every 15 minutes.

(4) Apply a splint.

(5) Give patient two sulfadiazine tablets every 5 minutes until the twelve tablets are taken.

(6) If in pain, inject morphine.

g. Shock can occur as the result of an injury such as a wound, fracture, or even sudden nervous strain without physical injury. The symptoms are:

(1) Paleness.

(2) Semiunconsciousness.

(3) Cold and clammy skin.

(4) Weak and rapid pulse.

h. Treatment of shock:

(1) If there is a physical injury, stop the bleeding.

(2) Keep the patient warm.

(3) Elevate feet higher than head.

(4) If patient is in pain, inject morphine.

(5) Keep the patient quiet.

(6) Give him 100 percent oxygen.

i. In cases of severe pain use the morphine syrette in the following manner:

(1) Remove wrapper and transparent hood.

(2) Grasp wire loop and push wire in to pierce inner seal. Pull out and discard the wire.

(3) Paint the skin with tincture of iodine before injection. Thrust the needle through the painted skin at least half the needle's length.

(4) Inject solution by slowly squeezing the syrette from the sealed end.

j. Iodine is generally used only on minor wounds.

k. For burns, spread the burn ointment over the skin surface that has been damaged. A loose bandage should be applied to prevent infection and to keep the ointment from rubbing off.

61. Summary.—*a.* The rapid and correct treatment of an injury is most essential. For that reason, if it is possible, treat casualties while in flight instead of waiting to land. Many men have received first-aid treatment and then continued at their battle stations to help bring back the airplane safely.

b. Always remember to—

(1) Give plenty of oxygen quickly.

(2) *Never* leave a tourniquet on for longer than *15 minutes* at a time.

(3) Never take or let anyone remove the first-aid kit from any airplane. It is as much a part of the equipment of the airplane and flyer as the parachute or safety belt.

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